FUEL EFFICIENCY BOOKLET 2

Steam

ENERGY EFFICIENCY

BEST PRACTICE PROGRAMME

The imperial values given in parentheses in this Booklet are intended to be of the same order as, but not direct conversions of, the preceding SI units. All pressures are gauge unless otherwise stated.

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CONTENTS

CONTENTS

INTRODUCTION

1 INTRODUCTION

Steam is used for heating and process work as it is an ideal carrier of heat. Its three main advantages as a heat transfer medium are as follows:

- It transfers heat at constant temperature. This is extremely useful when dealing with heat sensitive materials.
- The temperature of steam is dependent upon the steam pressure. This results in a simple method of temperature control.
- It is compact in terms of heat content per unit volume. This means heat can be conveyed in simple piping systems.

Steam is often used carelessly resulting in systems becoming poorly maintained and thus inefficient. Even in the best regulated establishments there is bound to be some unavoidable wastage of heat, but having allowed for this comparatively small loss, it is necessary to see that the rest of the heat is put to good work. This Booklet is concerned with the more efficient use of heat in the form of steam.

Steam utilisation efficiency is not as easily measured as the thermal efficiency of a boiler and as a result it is frequently neglected. (For details on calculating the thermal efficiency of boilers, see Fuel Efficiency Booklets 14, 15 and 17, which cover the economic use of oil-fired, gas-fired and coal-fired boiler plant respectively.)

Often it is not noticed that a 'wisp' of steam is leaking from a joint, that insulation is missing, that steam traps are blowing steam and that boiler operators blow down the boiler on the basis of previous practice. Possibly, or even probably, the equipment using the steam is not giving optimum performance because it contains air, or is waterlogged due to faulty steam trapping. The production rate then falls.

In giving up its heat, the steam condenses but still retains some of the energy originally put into it by burning fuel in the boiler. This energy can be recovered and put to good use.

A neglected steam system can cause concern about its cost effectiveness both in terms of energy cost and productivity. The methods required to achieve optimisation are neither difficult nor costly. Few firms know what their steam costs are, yet this must be an important part in the costing of any product. Too often these are regarded as unavoidable overheads, although the return on capital expenditure to improve the steam system can be high.

There are various ways of making the generation and use of steam more efficient. In general they can be described under three main headings :

- Steam generation
- Steam utilisation (Section 3)
- Heat recovery (Section 5)

The main area for making savings at the point of generation is by the control of flue gas losses. This is discussed in Fuel Efficiency Booklets 14, 15 and 17. Another important quantifiable loss is blowdown loss.

With steam utilisation, the losses are split between heat losses in the system (leaks, etc) and heat loss by inefficient use at the place where it is needed.

Finally there is a discussion on heat recovery techniques which explores methods of utilising the heat left in steam once it has given up its latent heat.

INTRODUCTION

Sensible heat and latent heat

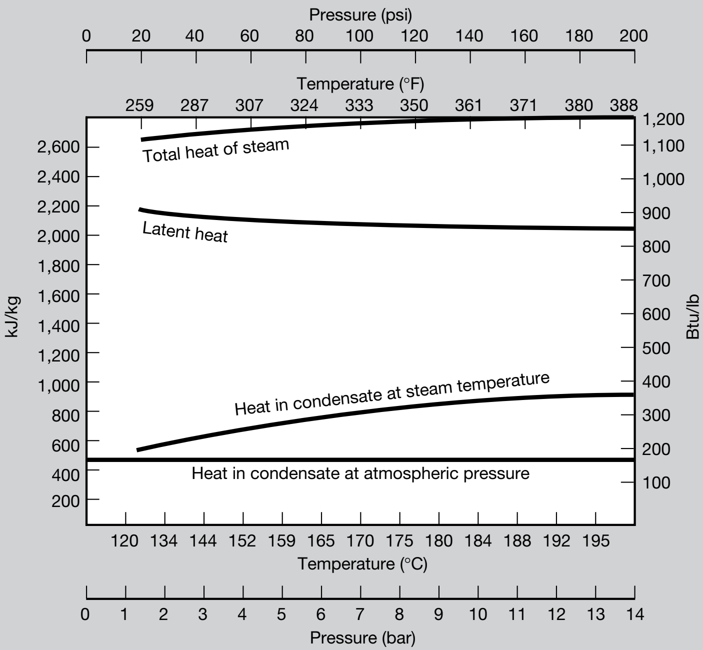
It is worth taking a little time, before getting into all the energy saving opportunities that exist with steam systems, to understand how steam is created and the two types of heat which have to be present for it to exist, i.e. sensible and latent heat.

When heat is added to water, its temperature rises at a rate of 0.5°C (1°F) for each heat input of 2 kJ/kg (1 Btu/lb) of water. This rise in temperature can be detected by the senses and is called sensible heat (419 kJ/kg of heat to convert water from 0°C to 100°C).

At normal atmospheric pressure, any further addition of heat to water at 100°C will not increase the temperature, but will cause some of the water to boil into steam. In order to change all the water into steam, 2,257 kJ/kg (971 Btu/lb) of heat would have to be added. The additional heat cannot be felt by the senses as a rise in temperature and is called the latent heat of vaporisation. Thus a total of 2,676 kJ/kg of heat is required to turn water at 0°C into steam.

If water is subjected to pressure it will not boil at 100°C (212°F) but at a higher temperature. This temperature is related to the

Fig 1 Heat content of steam



* All pressures are gauge unless otherwise stated

INTRODUCTION

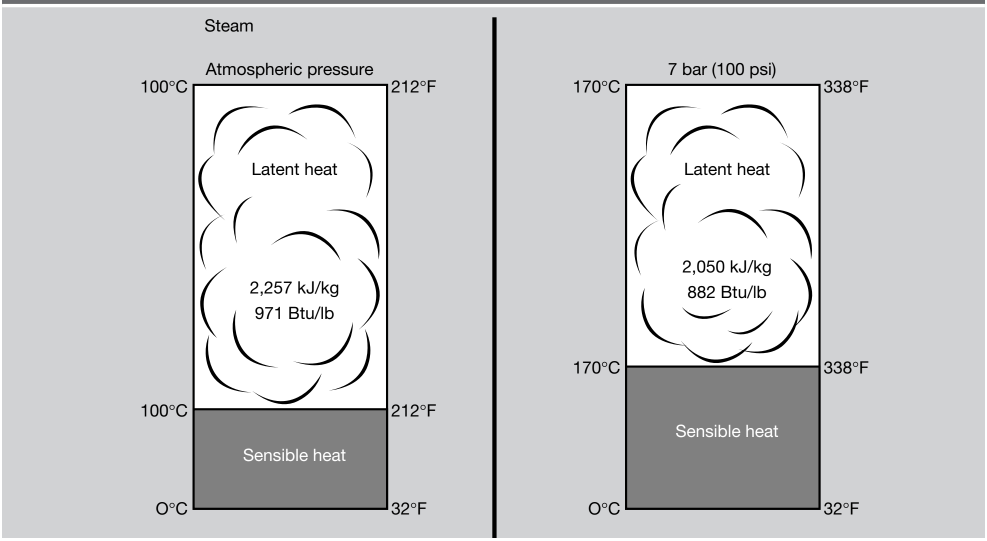
steam pressure and, as can be seen from Fig 1, the lower the steam pressure the higher the proportion of latent heat per unit weight of steam. This physical fact has an important bearing on fuel economy.

It can be seen from Figs 1 and 2 that the higher the steam pressure, the higher the steam temperature. This relationship can be used to achieve a temperature required by a process, critical in some cases, by matching it with the correct steam pressure. For greater accuracy, these relationships are normally given in the form of steam tables which are in Appendix 1. So if pressure is reduced to give greater economy it must be ensured that productivity is not upset by the lower temperature.

Many processes employing steam as the heating medium only make use of latent heat. Therefore, it is necessary to optimise the availability of latent heat and the driving force by good steam pressure control. Additionally, the heat in the condensate rises with steam pressure, and so the higher the steam pressure used for a process the greater the need to recover heat from the condensate in order to maintain high levels of efficiency.

It is shown in Fig 1 that the latent heat of steam decreases as the pressure rises. This means that the higher the steam pressure, the smaller the amount of latent heat (usable heat) available per kilogram of steam. Therefore, at higher

Fig 2 Comparison of latent heat content of steam at atmospheric pressure and 7 bar (100 psi)



INTRODUCTION

pressures more kilograms of steam are needed to supply a given quantity of latent heat.

Thus, from the point of view of steam economy, the lower the steam pressure, the lower the steam consumption for a given amount of heat. It is also true, however, that the lower the steam pressure, the lower the temperature and, therefore, the lower the rate of heat flow from a given surface area. This difficulty can sometimes be overcome by increasing the amount of heating surface.

Example of the effects of increasing surface area

A heating system, working at a pressure of 5.5 bar (80 psi), can be made to give the same heat output at a pressure of 2.4 bar (35 psi) simply by increasing the heating surface by 25%. If, for instance, a room contains four lengths of heating pipe then the total heating surface will be increased by 25% if an extra length of pipe is added. By doing this a saving of 4% is made. Further reduction in pressure to 0.34 bar (5 psi), and an increase in the heating surface of 75%, would result in a saving of 7%.

This principle should be borne in mind when designing heating systems, such as fitting heating coils in hot water tanks and installing heat pipes for air heating.

There are two points to be considered:

- As the boiler operating pressure is reduced, the specific volume of steam increases rapidly as the operating pressure falls below 7 bar (100 psi). The rapid rise in the specific volume of steam promotes carry-over and water is not a good heat conductor.
- It is not possible to increase the heating surface of all kinds of steam plant and equipment.

2 BLOWDOWN

Blowdown is a necessary operation for boiler plant in order to maintain correct water conditions. The water fed into the boiler contains dissolved materials, and as the water is evaporated into steam these are left to concentrate in the boiler, either in a dissolved or suspended state.

It is, therefore, necessary to control the level of concentration of the solids and this is done by the process of 'blowing down', where a certain volume of water is drawn off and is automatically replaced by feedwater, thus maintaining the optimum level of total dissolved solids (TDS) in the water. If not carried out, boiler failure may occur and there will be carry-over and foaming, the latter resulting in a large quantity of water being carried forward in the piping system to the process. This problem calls for the careful monitoring and supervision of the water conditions in all boilers, particularly the modern shell type packaged units which are even more vulnerable than earlier types because of their small water capacity and limited steam space in relation to their output. It is important to recognise that blowdown can, if incorrectly carried out, be a significant source of heat loss second only to the heat carried out of the boiler in the flue gases.

There are two aspects to consider:

- The first and most important is that the quantity of blowdown should not exceed the minimum amount necessary. Anything in excess is a waste of energy. Proper control is most important.
- When this has been achieved, the recovery of heat from the blowdown should be

BLOWDOWN

examined to see whether it is economical to do so. This is discussed in Section 5. On average about 50% of the heat may be recoverable.

Fig 3 Blowdown drain valve

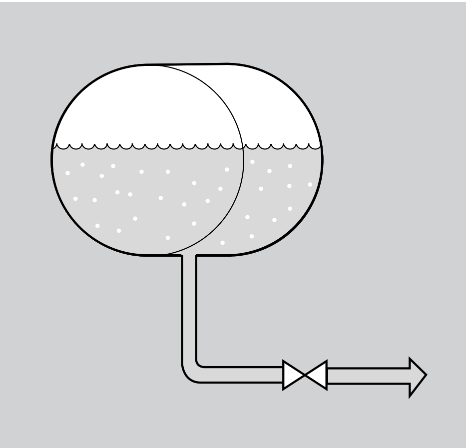
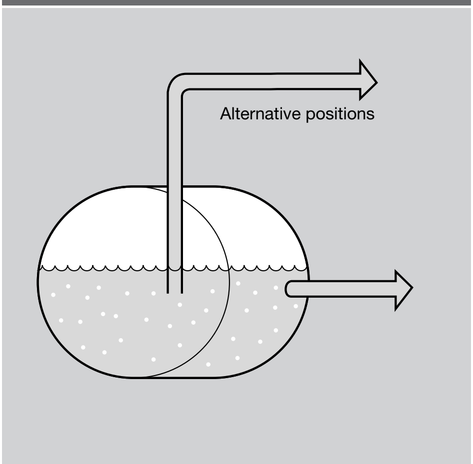


Fig 4 Boiler blowdown points



Methods of blowdown

There are two methods of blowdown:

- intermittent, taken from the bottom of the boiler (see Fig 3) to remove any sludge that has settled. This is generally a manual operation carried out once per shift in a series of short, sharp blasts, with the amount of blowdown being estimated from the reduction of level in the gauge glass. This was the traditional method utilised with shell boilers.
- continuous, as a bleed from a source near the nominal water level (see Fig 4). In more recent years this has become 'step-continuous', the valve being opened or closed cyclically from a time signal, or from a signal derived from some property of the boiler water, such as electrical conductivity.

In modern practice, both intermittent and continuous blowdown methods are used, the former mainly to remove suspended solids which have settled out and the latter to control TDS. It is important to carry out the intermittent blowdown sequence at periods of light load. It is also important that this should not be neglected, otherwise, with unfavourable water, sludge may build up beneath the boiler furnace tubes to such an extent that heat transfer is impeded and the furnace tubes fail.

For a fuller description of blowdown methods see Good Practice Guide 30 - *Energy efficient operation of industrial boiler plant*.

BLOWDOWN

How much do you blowdown?

The following provides a simple checklist for estimating the quantity of blowdown from a boiler, if not already known:

1 If the TDS level of the boiler feedwater (mixture of condensate return and make-up) can be obtained, the required percentage of blowdown may be calculated as follows:

$$\% \text{ blowdown} = \frac{S_f}{S_b - S_f} \times 100$$

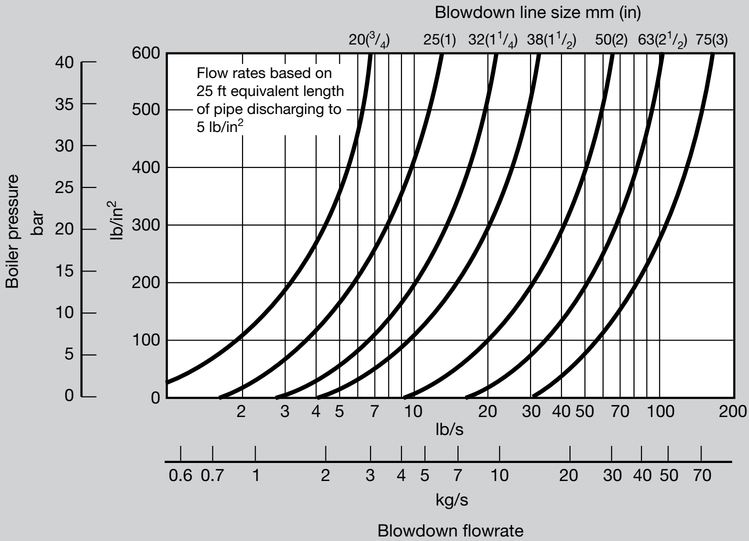
Where S_f = TDS level of feed water in ppm

S_b = desired TDS level in boiler in ppm.

2 For existing plants, the present blowdown method may consist of blowing down, say, 1 inch from the gauge glass at regular intervals. This may be converted to a volume by estimating the water surface area of the boiler (width x length), and multiplying this by the frequency of blowdown, to give an equivalent continuous blowdown flowrate. Remember that this will be related to the present average steam generation rate.

3 Alternatively, the existing blowdown method may consist of opening the bottom blowdown valve for a given time at certain intervals. For the standard full-bore valve the flowrate is controlled by the length and bore of the blowdown line, and the boiler

Fig 5 Blowdown flowrates

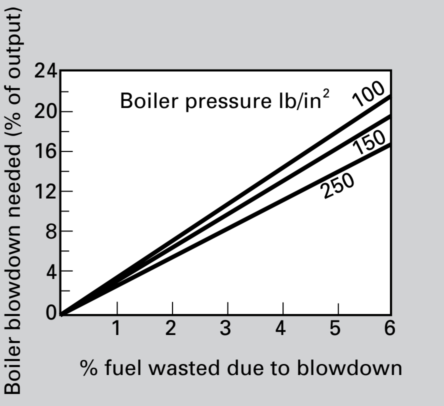


BLOWDOWN

pressure. Fig 5 may be used for estimating the flowrate when the valve is open, and from the figure obtained, an equivalent continuous blowdown flowrate may be calculated. Again, this will be related to the average generation rate.

NOTE: The blowdown flowrate given in Fig 5 is in kg/second or lb/second, not lb/hour as is commonly used for boiler generating rates.

Fig 6 Percentage of fuel wasted in blowdown



What does it cost?

To buy water, treat it, pump it into a boiler, heat it to boiling point and then throw it away may be necessary to satisfy the requirements of steam raising. Unless it is properly controlled, however, it can be very wasteful of energy and money. It should also be remembered that constant quality of water should not be taken for granted and intermittent blowdown practices may fail to cope with such a difficulty. The costs of blowdown are seldom obvious, because they are hidden in the overall boilerhouse costs, in water and its treatment costs and in fuel costs.

Fig 6 shows graphically the relationship between blowdown and the percentage of fuel carried away as sensible and latent heat in the blowdown.

Typically, 97.7% of the fuel is used directly for steam raising and 2.3% is contained in the blowdown. 2.3% may sound trivial but if a boiler with a capacity of 4,500 kg/h (10,000 lb/h) of steam is in operation for 3,000 hours a year it represents a fuel consumption of about:

- 24,000 m^3 or 8,600 therms of natural gas
- 22,000 litres or 4,900 gallons of oil
- 39 tonnes or tons of coal

To this must be added 1,350,000 litres or 300,000 gallons of water, water treatment, pumping and effluent discharge costs, bringing the total cost, depending upon the fuel, to between £2,500 to £5,000 per annum (based on 1992 prices). If the boiler is in operation 8,000 hours a year these costs would rise to between £6,000 and £12,000.

3 STEAM UTILISATION

As operating efficiencies of boilers are usually quite high (75 - 84%), the efficiency of steam plant is quite frequently also considered to be high and utilisation efficiency is not generally considered. Steam leaks, lack of insulation, no return of condensate and no use being made of

Example of the effect of improved efficiency

An improvement in efficiency from say 45% to 55% actually represents a fuel saving of:

$$\frac{10}{45} \times 100 = 22.2\%$$

STEAM UTILISATION

flash steam potential can reduce overall efficiencies - fuel input to product - to below 50% and sometimes well below.

Significant cost savings can be made by:

- reducing heat losses from steam pipework distribution systems and exposed surfaces;
- ensuring that steam supplies, whether they are used for space heating or for production purposes, are maintained and controlled to desired conditions.

Since electricity is metered and charged for by the supplying company, its cost in bulk is known, but insufficient may be known about departmental or individual process costs. Few firms, however, know what their steam costs are, yet this must be an important part in the costing of any product. Too often these are regarded as unavoidable overheads. In some cases the total cost of these services is no more than 5% of the total production costs and they are, therefore, often thought to be of little importance. Nevertheless, large amounts of fuel and substantial sums of money can be involved. The full effect of the efficient use of factory services in relation to production costs can only be established when the individual costs are known to management (see Fuel Efficiency Booklet 1 - *Energy audits for industry*).

The total, or overall, cost of steam must depend entirely on the basic reason for costing. If the purpose of costing is to provide the industrialist with a true cost of individual products, it is essential that every expense, direct or indirect, in the generation and distribution of steam is included.

A cost analysis of steam production and its allocation to different processes is a useful tool for examining where cost reductions can be achieved. Although metering the steam continuously is extremely useful, doing so for each and every process may be impracticable. It is, however, relatively simple to measure the condensate produced from each process, and then establish a 'standard' from which costs and possible savings may be assessed for each process and/or separate building within the factory. The methods, principles and guidelines for steam metering are given in Good Practice Guide 18 - *Reducing energy consumption costs by steam metering.*

There are two stages for steam metering. As a first stage, metering the steam as it leaves the boiler house is preferable. The total cost divided by the amount of steam produced will give the cost per tonne. As a second stage, the steam can then be metered into each department, or to the major steam users. There will be some difference in the total steam metered into all departments and the steam delivered from the boiler house. This discrepancy is due to the distribution losses and provides a useful check on these losses. A sudden increase may indicate some damaged insulation, leaks or faulty steam traps.

In some plant, however, steam metering may not be practical. As an alternative to direct steam metering, and remembering that 1 kg of steam fully condensed forms 1 kg of water, it is sometimes more practical to measure the condensate from a unit of plant or a department, rather than the steam supply to it. In this way a 'standard' steam consumption for any individual piece of plant or equipment can be established which can be used, not only for costing purposes, but to confirm the savings achieved by any modifications.

If savings are made by the more efficient use

STEAM UTILISATION

of steam then these are reflected mainly in the fuel costs. Reducing the steam demand by 2,000 units an hour (whether the units are kilograms or pounds), cannot truthfully be said to have any effect on the sums allowed for depreciation of the boiler plant, plant insurance, labour, etc, all of which are standing costs, unaffected by the amount of steam the plant is producing. Therefore, for this purpose the cost of steam should be based on:

- fuel costs;
- fuel handling;
- water and water treatment.

A reduction in steam demand can, of course, have some effect on the electrical demand for boiler feed pumping, firing, etc, but this would be difficult to assess and is normally so small that it can be justifiably ignored.

At today's prices, fuel costs represent, in the average plant, some 80 - 85% of the total overall cost of steam. Evaluating savings on fuel costs alone can often give a simple but useful guide to the overall savings in cost achieved by steam economy.

One of the most common reasons for evaluating potential saving is to justify expenditure on equipment. This can often be achieved more simply by a direct calculation on the fuel saved rather than on a basic cost of steam.

Steam leakages

The most obvious source of heat loss on any steam plant is the loss associated with steam leakages from faulty valves, pipework flanges and joints. Such leakages are easily detected and should not be allowed to continue, since the wastage through even a small leak is significant.

Uninsulated surfaces

Heat can be lost due to radiation from steam pipes. Every square metre of uninsulated steam heated surface (both steam pipes and steam-heated equipment) means that at a pressure of 7 bar (100 psi), 9,300 kJ (8,850 Btu) of heat energy will be lost on an hourly basis, representing 5 kg of steam per hour, or 1 lb of steam from every square foot of uninsulated surface.

Here are the makings of a vicious circle: heat loss from exposed surfaces of pipework and machines may make working conditions unbearably hot, so the machine operator

Example of the effect of a leak

Consider the following :

- Steam Pressure 7 bar
- Hole Size 0.8 mm

Loss Equivalent:

- up to 2.5 tonnes of coal per year
- up to 1,500 litres of oil per year
- up to 570 therms of gas per year.

Example of the loss through uninsulated surfaces and flanges

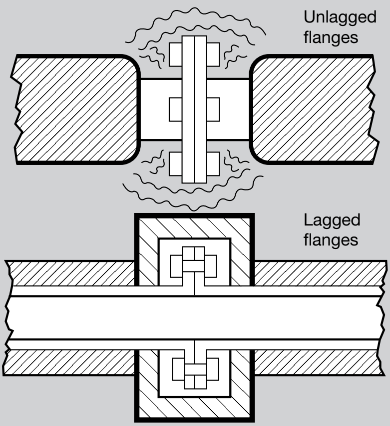
A 3m (10 ft) length of exposed 150 mm diameter piping carrying steam at a pressure of 7 bar can waste 5 tonnes of coal or 3,000 litres of oil a year.

If there were five uninsulated flanges on the same 150 mm diameter pipe, heat losses would equate to 5 tonnes of coal or 3,000 litres of oil being wasted a year.

STEAM UTILISATION

naturally opens a window to cool the shop; a cold draught blows over the exposed surfaces and further increases the heat wastage. The

Fig 7 Heat loss through uninsulated flanges



remedy is simple - insulating all the exposed surfaces of steam heated plant will reduce both heat losses and the need to open the window. Fig 7 shows box-type insulation for flanges. See Fuel Efficiency Booklets 8 - *Economic thickness of insulation for hot pipes* - and 19 - *Process plant insulation and fuel efficiency* - for further details.

Minimising the demand for steam

When the steam supplies are distributed as efficiently as possible to their point of use, steam consumption should be kept to an absolute minimum. User demand should be accurately assessed to determine minimum steam requirements, followed by on-going surveys carried out to highlight changes in demand or working practices.

Example of fuel loss due to overheating

Room temperature being maintained 19°C
Room temperature required 17°C
Outside air temperature 7°C

$$\text{Ratio} \quad \frac{19 - 7}{17 - 7} = 1.2$$

So from Fig 8 fuel wasted is 16-17%.

NOTE: Although the excess temperature is only 2°C, it results in a fuel wastage of 17%.

Unnecessary heat losses associated with space heating systems

By controlling the indoor temperature, either manually or preferably automatically, excess temperature can be avoided and the amount of work the steam system has to do can be reduced. Another way of reducing the amount of work to be done is to cut out unnecessary heating of corridors or rooms that are not in regular use.

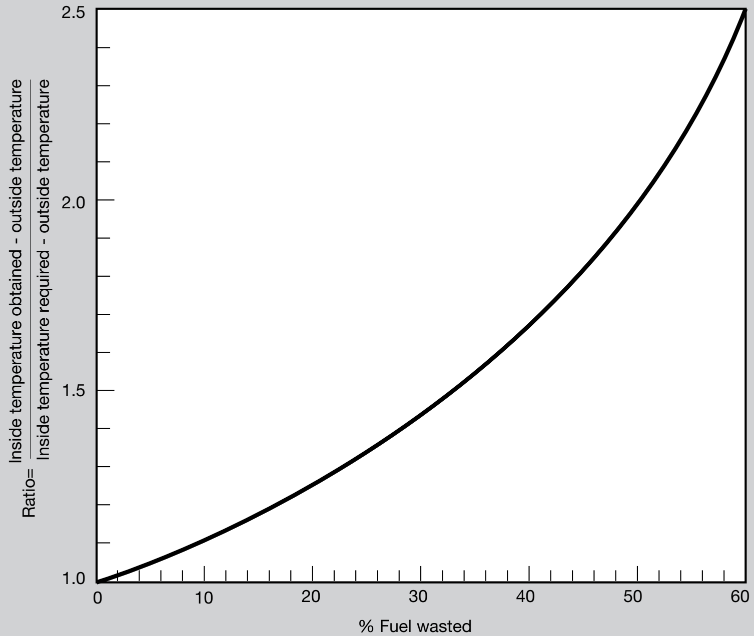
Fig 8 shows the fuel loss due to excess temperatures on heating systems and provides an example which shows how to ascertain losses under varying conditions.

One common way in which large workshop spaces are heated is by use of air input heater units as shown in Fig 9. By adjustment of the dampers, air flow can be varied from 100% fresh air intake, which is perhaps ideal for summer ventilation, to 100% recirculation during winter conditions.

The ideal winter conditions would be about 25% fresh air and 75% recirculation, but this will vary according to the ventilation requirements of the space concerned. It is obviously important that fresh air intake is kept to a

STEAM UTILISATION

Fig 8 Fuel loss due to excess temperatures



minimum for satisfactory working conditions. Any excess will considerably increase the fuel used, and so the setting of the dampers should always be in responsible hands.

The following aspects should be avoided:

- failure to reset dampers after the summer ventilation;
- the fans of unit heaters switched off, but steam valves left open.

Example of the wastage through unnecessary steam use

A unit heater with a normal output of say 44 kW (150,000 Btu/h), with steam at a pressure of 7 bar will condense about 77 kg of steam an hour on normal running. With the fans cut out, the steam consumed by the heater will be in the order of 4.5 kg of steam an hour. This is quite a substantial waste because the heat simply rises to the roof space of the building and escapes without having done any useful work.

STEAM UTILISATION

Fig 9 Air input heater

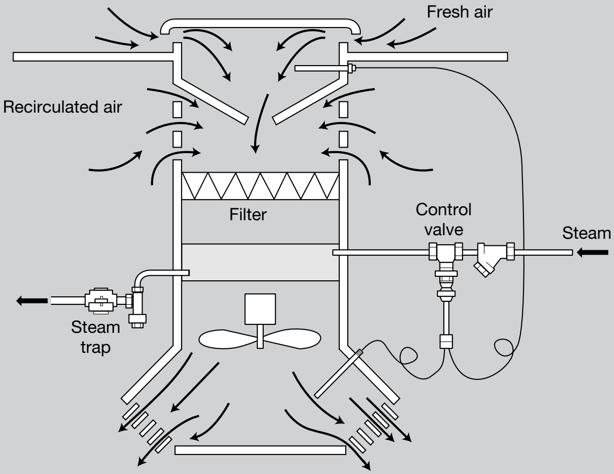
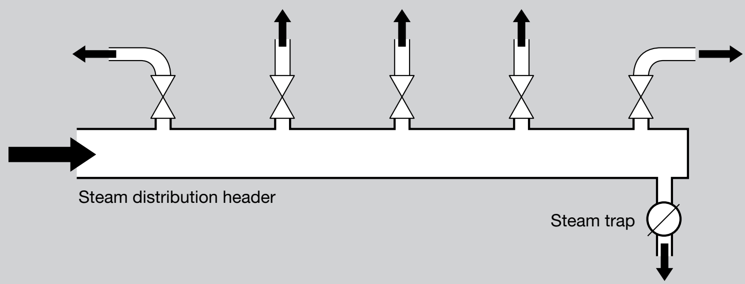


Fig 10 Distribution system



STEAM UTILISATION

Example of distribution losses

An unnecessary 3 m of 50 mm diameter steam pipe can waste upwards of £12 worth of fuel a year in a plant working eight hours a day, five days a week, or over four times this amount if the plant is in continuous operation. Insulation could reduce the loss by about 70 - 75%.

Example of losses through partial loading

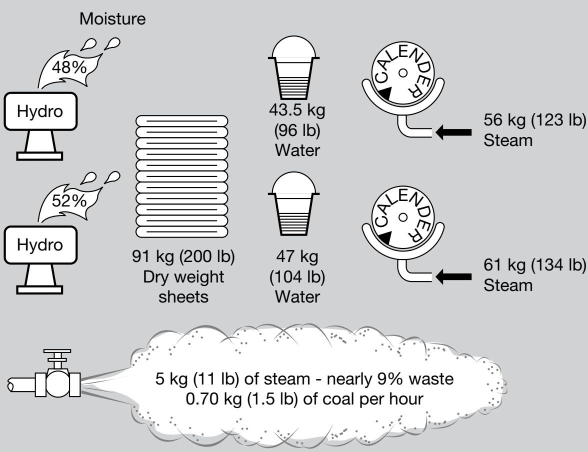
A plant using say, 907 kg (2,000 lb) of steam an hour, eight hours a day, five days a week, when only 50% loaded, is wasting about 112 tonnes (110 tons) of coal or 66,000 litres (14,500 gallons) of oil a year. Furthermore, the plant could be using twice as much electricity as is necessary.

Unnecessary losses associated with distribution systems

Shortening and re-routing distribution pipework to reduce heat losses without interfering with the process sequence can often pay handsome dividends. In all new system designs, plant should be grouped as close as is practicable to the steam supply main to minimise distribution losses.

Dividing a distribution system into zones and utilising suitable isolation valves (see Fig 10), enables one section of the factory to work overtime without maintaining steam in the mains to all other departments.

Fig 11 Steam wastage due to insufficient mechanical drying



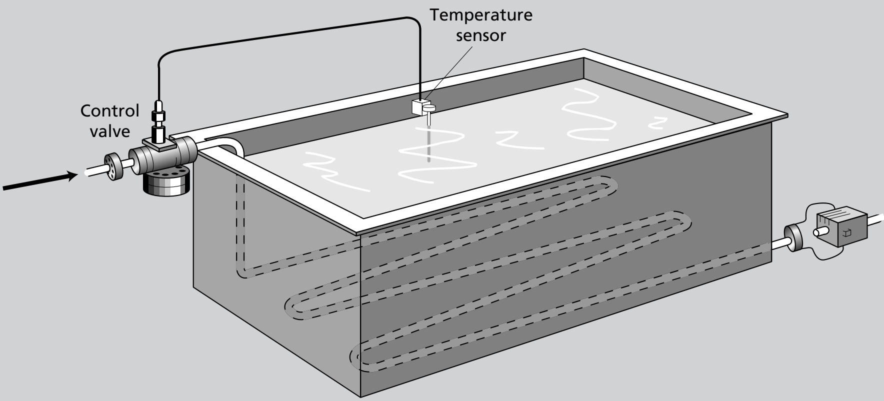
STEAM UTILISATION

Examples of waste through excessive process temperatures

Consider the case where dyeing in 2,300 litre liquor vats has for generations been done at 100ºC. The liquor had to be heated from cold to 100°C when starting up, and the material had to be heated by the liquor from cold to 100°C, at which temperature it was taken out of the dye vats. By experiment it was found that the dyeing could be carried out just as satisfactorily at 60°C, reducing steam consumption by nearly 50%.

In a recent example, five open process liquor tanks were found to be operating at 82°C when it was known that 65°C was adequate for the particular process. This unnecessary overheating wasted 52,300 litres (11,500 gallons) of fuel oil a year at a cost of about £6,300 - a wastage which could be prevented by an initial outlay of about £1,500 on temperature control equipment, as shown in Fig 12, for the five open process liquor tanks.

Fig 12 Temperature control of process tank



STEAM UTILISATION

Unnecessary losses associated with process plant

In industry a tremendous amount of heat is wasted by steam being made to do work which is unnecessary. Air heater batteries, for example, which provide hot air for drying, will use the same amount of steam whether the plant is fully or only partly loaded. So, if the plant is running only 50% loaded for the whole of an eight hour day, it is actually using twice as much fuel as is necessary to do the job. By modifying the routine so that the plant is fully loaded throughout the whole of the working period, and by shutting the plant down when no production material is available, considerable savings can be effected.

Mechanical drying is nearly always the most economical way of removing the bulk of water from very wet material. Steam can then be used to complete the process. For this reason, hydro-extractors, such as spin dryers, squeeze rolls, presses etc., are used in many drying processes initially to remove the mass of water. The efficiency with which this operation is carried out is most important. A careful watch should be kept on the efficiency with which the mechanical devices for moisture removal operate. Bad loading, slipping drive belts and worn rollers will also contribute to fuel wastage.

Fig 11 shows an example of a laundry drying sheets. For the same finished product the steam use increased by 9% when insufficient mechanical drying took place.

Heat losses associated with excessive process temperatures

Excess temperature in domestic hot water supplies, process hot liquor for dyeing and similar processes are further examples of steam being made to do more work than is necessary.

4 HEAT TRANSFER FROM STEAM

The heat transfer rate from condensing steam to a surface is very high, but can be seriously impeded by films of air or water. Appropriate air and steam condensate removal techniques will improve the overall efficiency of heat transfer.

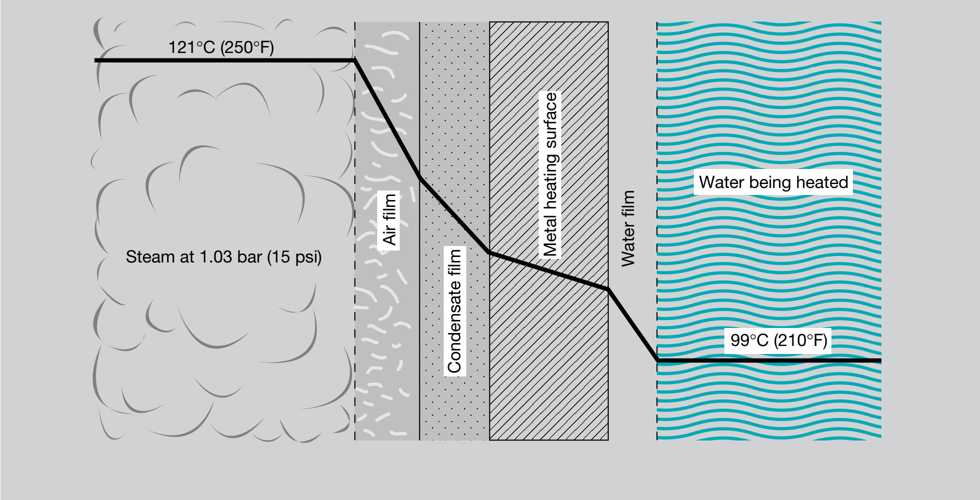
The centre section of Fig 13, i.e. the metal walls, is the heating surface of any process steam plant in which the steam does not come into direct contact with the material being heated. Firstly, on each side of this wall will be a scale film which creates considerable resistance to the flow of heat to the product. Often it is possible (and it always pays) to clean the surface regularly. Two further films, air and water, have to be removed as rapidly and completely as possible otherwise heat transfer and process output efficiencies are reduced.

The water film is between 60 and 70 times more resistant to heat transfer than iron or steel, and 500 to 600 times more resistant than copper.

The effect of the air film is even more drastic and is, in fact, more than 1,500 times more resistant to heat transfer than iron or steel, and no less than 13,000 times more resistant than copper. A film of air of 0.025 mm (1/1000 in) thickness has a resistance to heat transfer equivalent to a wall of copper 330 mm (13 in) thick.

HEAT TRANSFER FROM STEAM

Fig 13 Effect of high resistance to heat flow



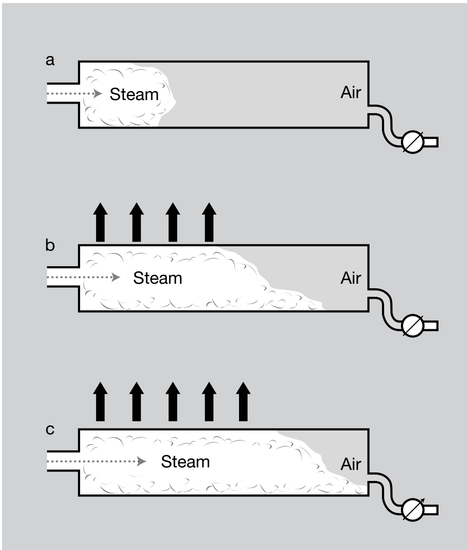
The practical effect of air and water films on process output is shown in Fig 13. Steam at approximately 1 bar (15 psi) pressure is being used to provide a process temperature of 99°C. By reducing the thickness of both of these films it is possible to either decrease the steam pressure for the same process temperature, or increase the process temperature for the same steam pressure.

The effect of air and water films on process output is not an isolated occurrence. It occurs in all steam-heated processes and will continue to occur unless some action is taken to reduce the thickness of the air and water films on condensing surfaces.

Dealing with air films

Air accumulates in all steam spaces when steam supplies are turned off and systems are allowed

Fig 14 Behaviour of trapped air



HEAT TRANSFER FROM STEAM

to cool. When steam supplies are turned on, air (and incondensable gases) has no option but to mix with the steam unless it is allowed to escape from the system.

It is, therefore, important to ensure that pockets of entrained air are removed before they have an opportunity to mix with the steam. In the majority of process plants where the cross-section of the steam space is relatively small, the general behaviour of the steam when it initially passes into a system is to push pockets of air ahead of itself, so that the air is collected at some point remote from the steam inlet to the system.

Fig 14 shows this behaviour, where once the steam is turned on, it pushes and compresses the air into a remote place where it will form a cold spot within the system.

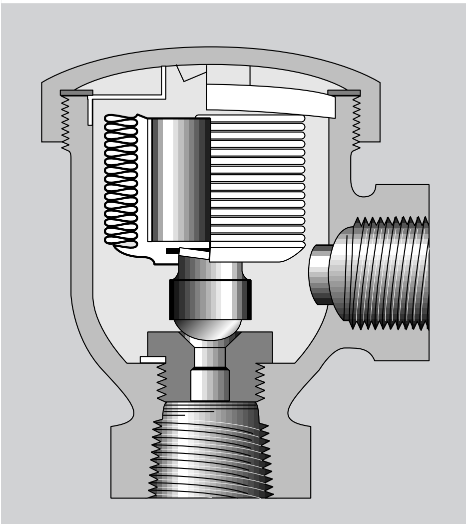
As a result the system cannot warm up quickly and uniformly, and in many cases the cold spot can cause distortion. The air will not necessarily remain at this spot - the flow of steam into the system may be turbulent and will agitate some of the air which has collected at the remote point. An air/steam mixture is therefore created which is undesirable, since it lowers the effective temperature of the steam. In addition, the steam component of this mixture will give up its latent heat through the wall of the system heating surface. As it condenses it will liberate the air component of the mixture, depositing it to add to the existing resistant films already in place.

The removal of air is essential and can be carried out either by manual or automatic air venting. Manual air venting has the disadvantage of relying on an operator knowing just when and how often a cock should be opened and, more difficult still, knowing when to shut it again, especially as an air/steam mixture looks exactly like steam. A better choice is an automatic air vent.

It is not sufficient, however, just to make provision for air venting - the speed of air venting must also be considered. During the stage when steam is passed into a system, provision must be made for the rapid removal of air, to reduce the possibility of air being diffused and mixed with the steam. Also, the quicker air is removed, the quicker the system steam space will be fully occupied with steam, reducing the time taken for the system to warm up to production temperature.

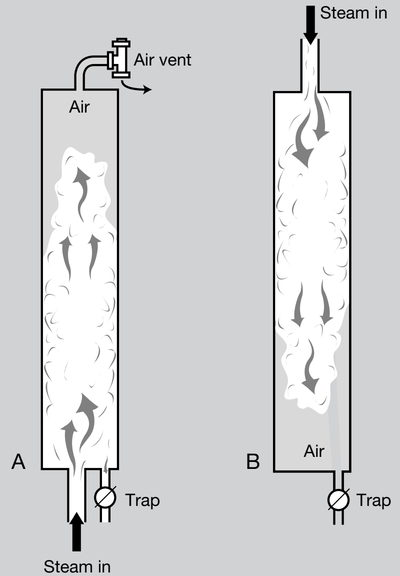
Since the air and steam are at different temperatures, a simple thermostatic air vent can be used. It is advantageous, whenever possible, to use a thermostatic air vent which combines

Fig 15 Balanced pressure air vent



HEAT TRANSFER FROM STEAM

Fig 16 Positioning of air vent

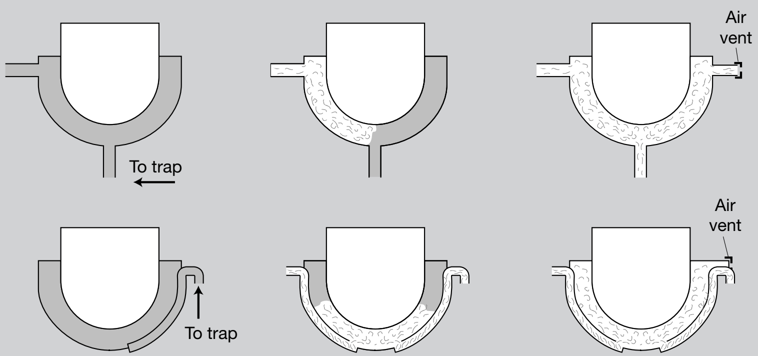


high capacity with the ability to stay open until steam temperature is almost reached, regardless of steam pressure variations. This is a characteristic of air vents which operate on the balanced pressure principle. A typical example is shown in Fig 15. Air vents with balanced pressure elements have another advantage. An air/steam mixture has a lower temperature than steam alone at the same pressure, and this difference can be sensed by these elements; therefore, whilst they will close in the presence of steam, they will allow an unwanted air/steam mixture to be discharged.

Positioning of air vents

The position of a steam inlet connection and the shape of a steam space have an important bearing on where air is deposited, and it is, therefore, not possible to lay down any hard and fast rules about where to position air vents. The

Fig 17 Air venting of steam jacketed boiler pans



HEAT TRANSFER FROM STEAM

final position must be decided for each particular item of plant, based on some knowledge of the shape of the steam space and the position of the steam inlet relative to the condensate outlet. Indeed, the choice of trap type and its ability to handle air may also be involved. Two examples are given which demonstrate the need for careful consideration of this matter.

Fig 16 shows two pieces of plant, identical in shape and size. In both plants condensate is drained from the bottom. In plant A the steam inlet is also at the bottom, so when the steam is turned on it will push the air ahead of it to the remote point which is at the top of the steam space. The best position for the air vent is, therefore, at the top of the steam space so that the steam trap would be required to pass little, if any, air. In plant B, however, the steam will push the air downwards. Here provision must be made for getting rid of the air, either by fitting an air vent or, more usually, by fitting a steam trap which has high air venting capacity, such as a float and thermostatic type.

In Fig 17 two types of steam jacketed boiling pans are shown. The upper row shows the simple fixed type with side steam inlet and bottom condensate outlet; the lower row shows the tilting type pan with the steam inlet through one trunnion and the condensate outlet through the other trunnion. In the left-hand pictures, the jackets are seen to be full of air. In the middle pictures, steam has entered the jackets and, although some air may have been discharged from the drain traps, a significant volume of air is shown to have accumulated at the upper part of each jacket, mainly at the side opposite the steam inlet; this is the most suitable venting point. The right-hand pictures show air vents in position and the jackets clear of air.

Condensate films

When the steam has released its latent heat to the heating or process system, condensate will have collected. If condensate is allowed to accumulate it will very soon cover the heated surfaces, preventing effective heat transfer, so arrangements must be made to discharge the condensate from the steam space.

Wet and dry steam

The fraction of pure steam in each kilogram of steam and water mixture passing from the boiler is called the dryness fraction (e.g. 5% of moisture in steam has a dryness fraction of 0.95).

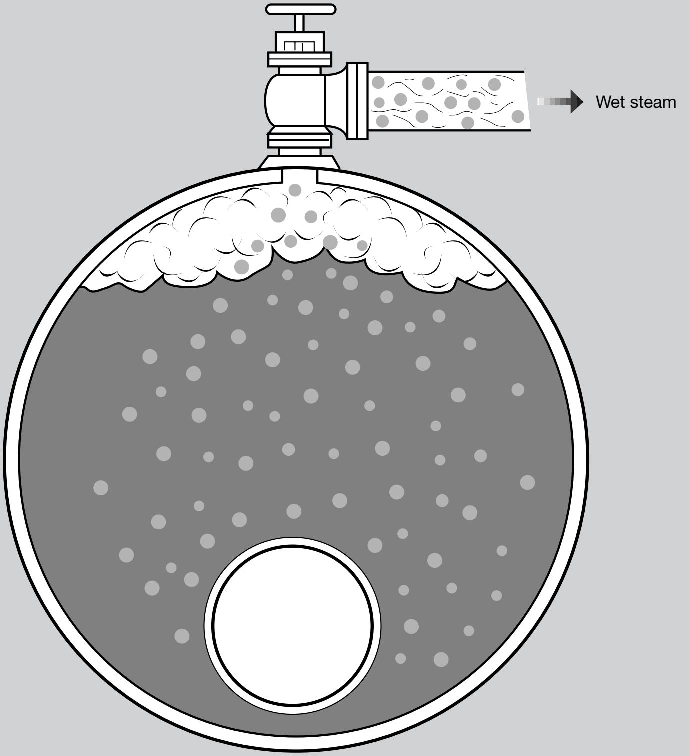
On most boiler plants there is a certain amount of carry-over water, which is mixed with the steam in fine droplets as steam bubbles on the surface of the boiling water burst (see Fig 18). Moisture in steam means that it has its normal quota of sensible heat but is short of latent heat.

When steam comes into contact with a surface that is to be heated, it gives up its latent heat and condenses, forming an insulating film. Any moisture in the steam increases the thickness of this insulating layer. For optimum system efficiency, it is therefore necessary to ensure that the percentage of moisture in the steam generated at the boiler is kept to a minimum.

It may appear that the simple solution to the problem of steam quality is to tackle the problem at the source, the boiler plant. Indeed, everything should be done to improve steam

HEAT TRANSFER FROM STEAM

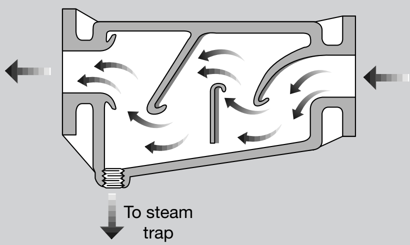
Fig 18 Carry-over



quality as it leaves the boiler by eliminating peak demands, by avoiding the overloading of boilers, and by careful attention to the boiler treatment chemicals and the way in which they are applied.

The very nature of steam generation under commercial conditions, however, makes it impractical to avoid some carry-over of water particles, which is aggravated further by steam

Fig 19 Steam separator



HEAT TRANSFER FROM STEAM

condensate, that is picked up by the steam as it passes through the pipework distribution system.

One solution to this problem is to install a steam drier, perhaps better known as a steam separator (see Fig 19). This is a device fitted into the steam main and changes the direction of the steam flow; it causes the entrained water particles to be separated out and delivered to a point where they can be drained away as condensate through a conventional steam trap.

The position of steam separators is important. A separator near the boiler can dry the steam before it passes into the distribution system, but steam will lose some heat by condensation and as a result will arrive wet at the point of use. With a separator installed near to the point of use, the steam will be fed to the equipment fairly dry and the amount of condensate present is reduced.

Steam traps and their management

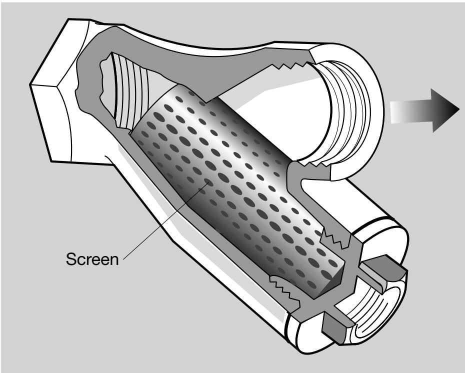
The most satisfactory method of releasing condensate is by automatically regulating the discharge of water by the proper use of appropriate steam traps.

Traps can, however, waste steam or fail to keep the steam plant clear of water, generally due to the ingress of dirt. Dirt and scale are to be found in all steam pipes, bits of jointing material are quite common and even nuts and washers are not unheard of. Once dirt becomes lodged in the valve seat of the trap, it will prevent the valve from shutting. Unless quickly cleared of the obstruction, the valve will be damaged and leakage of steam will continue until repair is carried out.

In most works, maintenance of steam traps is not a routine job, and unless some definite problems arise the principle seems to be to leave well alone. It should be remembered that steam traps are automatic valves and, in view of their importance as steam savers and as aids to plant efficiency, deserve considerably more care than is usually given to them.

Sight glasses fitted after a steam trap are useful for detecting leaking steam traps and are in fairly common use. They are of particular advantage when a number of steam traps discharge into a common return line; if it is suspected that one of the traps is blowing steam, the culprit can be quickly traced by an examination of the sight glasses.

Fig 20 Strainer



Strainers

To ensure that steam traps work properly it is necessary to keep them free from pipe-scale and dirt. There are two ways to prevent scale and dirt from getting into a trap:

- to have a dirt-collecting pocket in front of the trap (a short drop leg in the piping);
- to fit a pipe-line strainer in front of each trap.

HEAT TRANSFER FROM STEAM

The former is seldom satisfactory, as it will only prevent the heavier particles from reaching the trap. A pipe-line strainer (see Fig 20) is therefore preferred.

This strainer comprises a removable, perforated or meshed screen enclosed in a metal body which is very effective in stopping foreign matter from proceeding further. As it collects dirt, the removable screen will need periodic cleaning to prevent blockage.

The wrong use of the right steam traps

The wrong use of steam traps has a greater effect on waterlogging and loss of output efficiency than is generally realised. An example often

Fig 21a Group trapping

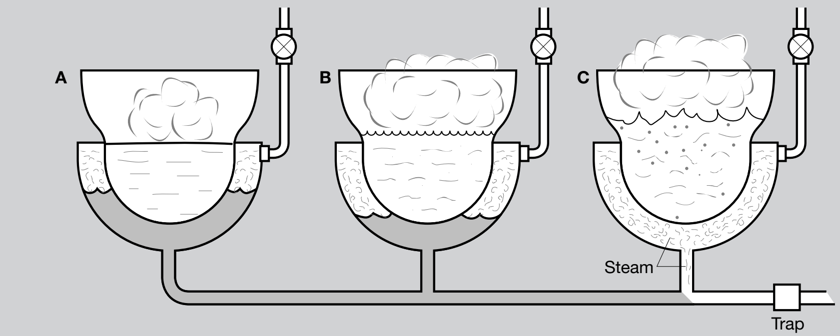
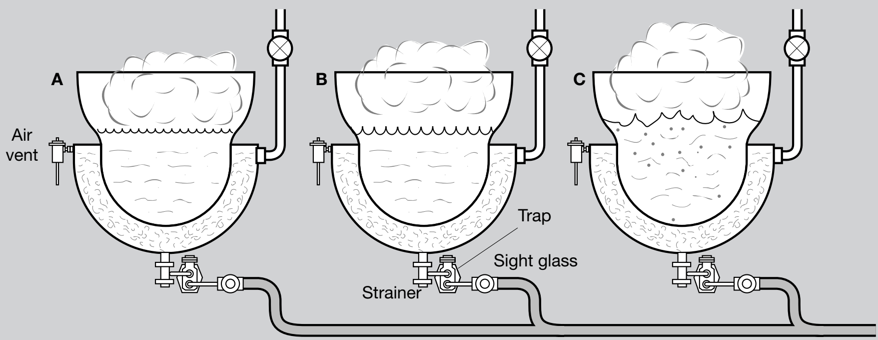


Fig 21b Individual trapping



HEAT TRANSFER FROM STEAM

occurs whereby a number of steam-heated plants drain to a single steam trap (group trapping).

Fig 21a shows three identical steam-heated vessels (they may be boiling pans, air heater batteries, laundry presses, or any other type of steam-heated equipment).

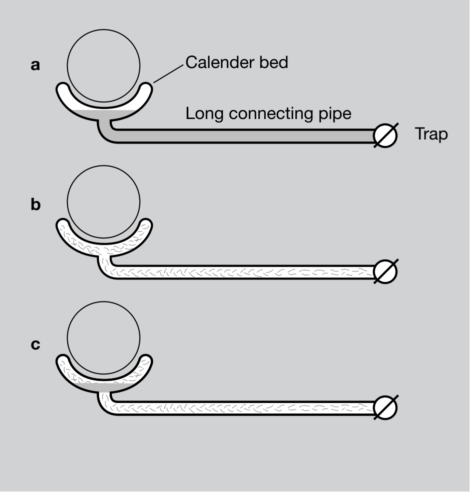
The drain from each vessel is connected to a common condensate pipe line leading to a single steam trap. The trap is in good working order and its capacity is adequate for the combined condensate load of the three vessels; however, the vessels become waterlogged.

Due to the high outlet pressure of Vessel C, which is towards the end of the process cycle, the pressure in the common condensate line will be higher than the pressure at the outlet of either of the other vessels which are in earlier stages. Consequently there will be a tendency for these vessels to waterlog, especially Vessel A. The same conditions will occur whenever a vessel is started up, irrespective of its position in relation to the common condensate line. Matters are made much worse because the vessel most recently started is forming the greatest load of condensate but is least capable of getting rid of the water.

Fig 21b illustrates a correct method for draining vessels. Each vessel is individually trapped, with the traps discharging to the common condensate line, and can discharge its load of condensate quite freely through its own trap at all times, irrespective of the conditions in the other vessels.

Figs 21a and 21b show that a single trap cannot be substituted for a number of individual traps.

Fig 22 Steam locking of a steam-heated calender



Positioning of traps

Another frequent source of waterlogging is the fitting of a steam trap in a convenient place rather than in the right place.

In Fig 22 of a steam-heated calender, the drain from the bed is separated from the steam trap by a long length of horizontal pipe. In Fig 22a, steam is off and water is standing in the bed and the connecting pipe. In Fig 22b, steam has been discharged through the trap, and the bed, pipe and trap are now full of steam. The trap will be closed and will remain closed as long as steam is present in the pipe, but condensation is taking place in the bend and water is collecting in the base (Fig 22c). This water cannot be discharged because the trap is steam-locked. Until the steam in the pipe condenses the trap will remain closed and the calender bed will gradually waterlog.

HEAT TRANSFER FROM STEAM

This will happen every time steam follows water into the collecting pipe. The remedy for steam locking is either to:

- move the trap as near as possible to the bed outlet;
- fit a steam lock release device, when the steam trap is to be fitted in a position where it is easily accessible for maintenance, and a long length of horizontal pipe is unavoidable.

Example of the waste due to open by-pass valves

At 7 bar, a 13 mm bypass valve inadvertently left open can waste as much as 0.5 kg of coal a minute.

Accumulation of air in steam traps

A similar problem can arise from a collection of air in the steam trap, although the result will be even worse than locked steam because the air cannot condense and the trap will not open. To overcome this it is not unusual to find by-pass valves around steam traps cracked open or air vent cocks left blowing. These solutions overcome the difficulty of air-binding but only at the expense of much wasted steam. The question of air-binding of steam traps should not be confused with air accumulation in steam-heated vessels - the problems are quite separate.

Steam traps of the thermostatic type cannot air-bind. Mechanical traps, such as the float or bucket type, will air-bind unless they are fitted with an automatic air release. Certain float type traps are fitted with an internal thermostat which is wide open when cold, so that when the steam is first turned on the air in the trap is quickly discharged; any air that collects when the trap is working cools the thermostat and is discharged, bringing the trap into operation again.

Traps of the thermodynamic type will generally air-bind. Hand air cocks on steam traps, like hand condensate drains, depend on the skill of the operator; if the operator forgets to open them, the traps will air-bind; if the operator leaves them open, steam will escape and be wasted.

An efficient method of overcoming these difficulties is to fit an automatic air vent in a by-pass line around the trap, or in the case of float traps, in the trap body, and so make the air release automatic.

Waterlogging and waterhammer

Another problem can occur when coil-heated tanks are being drained. Unless the problem of keeping the heating coil free of condensate is fully considered when fitting the coil, efficiency can be very much reduced by waterlogging.

Fig 23a shows a tank heated by a 50 mm (2 in) bore pipe coil. The pipe is led in at the top, is coiled round the bottom of the tank and is brought out at the same bore, and is then reduced to whatever size best suits the steam trap which has been installed to drain it. Before the steam is turned on, water has collected and sealed the coil at the base.

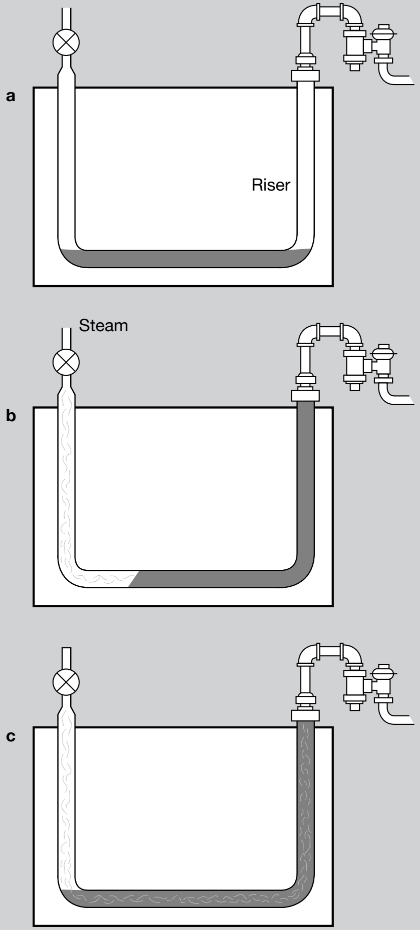
When steam is turned on (Fig 23b) the water is discharged and steam reaches the steam trap which then closes. Condensate again collects in the bottom of the pipe coil and it becomes waterlogged. Its heating effect is reduced

HEAT TRANSFER FROM STEAM

Example of steam condensation

An insulated 100 mm line, 30 m long, carrying steam at 7 bar with a surrounding air temperature of 10°C, will condense approximately 16 kg of steam per hour. This is probably less than 1% of the carrying capacity of the main. Nevertheless, it means that at the end of one hour the main would contain not only steam, but 16 litres of water; at the end of two hours 32 litres and so on.

Fig 23 Waterlogging of steam coils



because, until the bottom of the 50 mm (2 in) riser is sealed, steam can reach the trap and it is unable to release any condensate.

When enough waterlogging has taken place the condensate rises to the trap and some of it is released (Fig 23c), but as soon as the steam can leak past the condensate it does so and the pipe is never really free of water. For this reason it will never give maximum heat output.

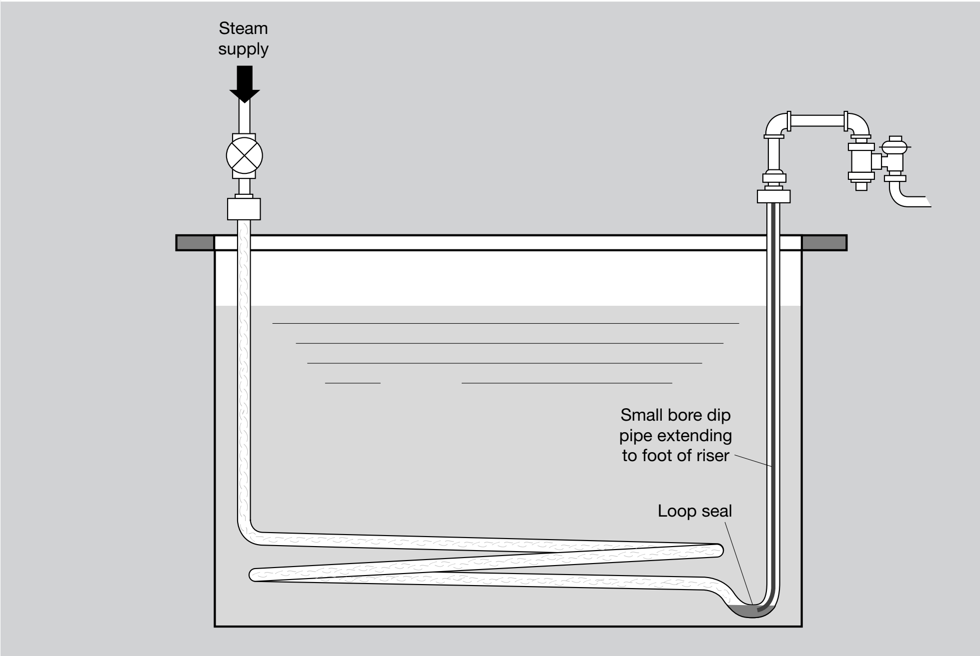
Apart from waterlogging, which will reduce output, waterhammer could occur with the arrangement of piping as shown in Fig 23, and this can cause serious damage to steam traps and other pipe fittings. To overcome this, a slight alteration in the pipe is necessary, as shown in Fig 24.

Waterhammer, which is associated with condensate, can often be traced to faulty steam trapping. To overcome this the following should be considered:

- Whenever possible, the main should be run with a fall of no less than 12.5 mm (1/2 in) in 3 m (10 ft) in the direction of the steam flow.
- Drain points should be located, on average, at intervals of 30 - 45 m (100 -150 ft) along the length of any steam main to collect and remove water. Any low point in the main, formed by natural contour in the layout, should be similarly drained.
- Large bore drain pockets should be provided to give adequate drainage. The ideal

HEAT TRANSFER FROM STEAM

Fig 24 Overcoming waterlogging of steam coils



situation is to have a pocket of equal diameter to the main. The drain pocket is best arranged as shown in Fig 25a. Provision of a small stub on a large bore main (Fig 25b) will not provide adequate drainage.

- The practice of fitting a concentric reducer on a steam main and when changing system pipe diameters is a common cause of waterhammer and should be avoided. This is shown in Fig 26a where the bottom of the main is always waterlogged. The correct way to drain the main and so avoid waterhammer is to fit an eccentric reducer as shown in Fig 26b.

- Waterhammer may be caused by opening steam supply valves too quickly. To prevent this, stop valves should always be opened slowly and carefully.

HEAT RECOVERY TECHNIQUES

Fig 25a Correct drainage of steam main

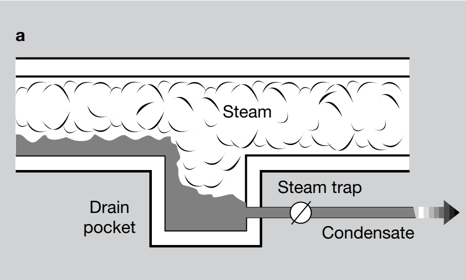


Fig 25b Incorrect drainage of steam main

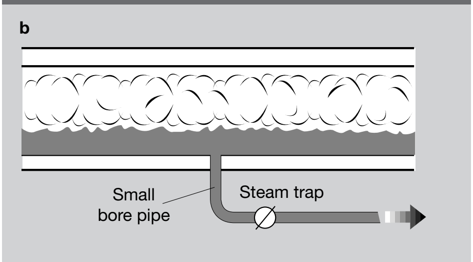
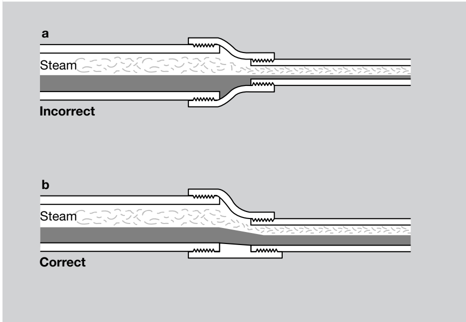


Fig 26 Reduction in pipe size



5 HEAT RECOVERY TECHNIQUES

Heat recovery can take place throughout the steam system:

- at the boiler, from the flue gases - see Fuel Efficiency Booklets 14, 15 and 17 for further details;
- from boiler blowdown;
- from flash steam;
- from condensate return.

Blowdown heat recovery

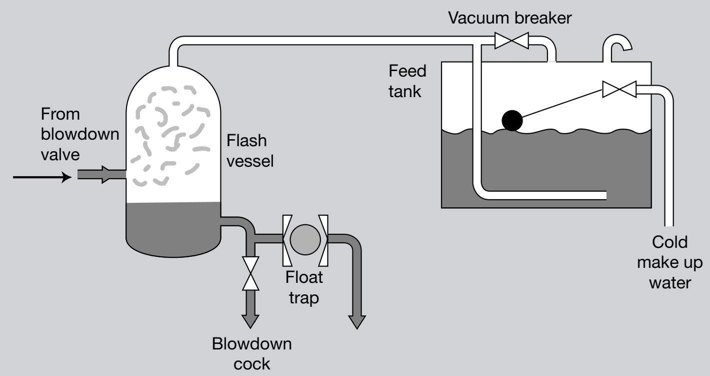
Waste heat recovery from a continuous blowdown system is generally more manageable than from an intermittent system, because with the former the supply and demand are constantly matched.

Where more than one boiler is operated on an intermittent system, it is advantageous to stagger or automatically time the blowdown cycle in order to spread the availability of waste heat more evenly. This will enable waste heat recovery to be more economic, because the equipment required will be smaller and will run for a higher proportion of the time, thereby proving more cost-effective.

There are many methods to recover heat from blowdown, which are covered comprehensively in Good Practice Guide 30 - *Energy efficient operation of industrial boiler plant*. The simplest way to recover heat from blowdown is through direct use of the flash steam, which forms due to evaporation as the pressure falls through the blowdown valve. This is pure water, with no dissolved solids, and can therefore be added directly to the make-up water for the boiler. The blowdown and flash steam are taken to a flash vessel where the two are separated. The flash steam is then discharged through a sparge pipe in the feed tank (Fig 27).

HEAT RECOVERY TECHNIQUES

Fig 27 Heat recovery from blowdown flash steam



Condensate heat recovery

Condensate is ideal boiler feedwater due to its heat content and chemical suitability. The higher the temperature of the boiler feedwater, due to a high level of condensate return, the less work the boiler has to do in converting the water to steam.

Savings resulting from condensate recovery

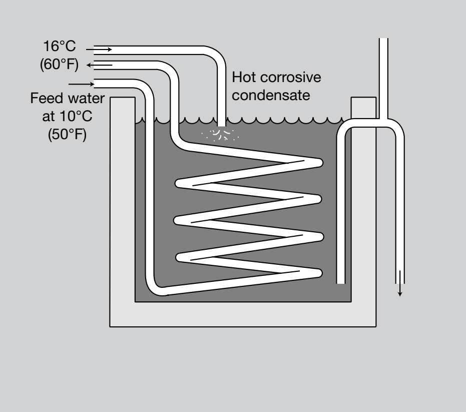
In fact, for about every 6°C (11°F) rise in feedwater temperature 1 per cent less fuel will be used in the boiler. Also, by raising condensate return, raw water usage will be reduced, which presents further savings.

There are however some exceptions where condensate recovery is not necessarily the best option.

- The distances involved with very large sites may make condensate return uneconomical. Long distances between the boilerhouse and the point of steam consumption will result in much of the heat contained in the condensate being lost by the time it returns to the boilerhouse, even if there is good insulation. Therefore, the cost of installing condensate return mains cannot be offset by fuel saving. It may still be a worthwhile proposition to return the condensate to the boilerhouse, even if it does arrive there cold, if good quality boiler feed water is scarce or if the cost of chemically treating the raw water is high. If there is no scarcity of water and feed treatment costs are low, it could be more advantageous to divert the condensate to meet some demand for process hot water, and in so doing make maximum use of its heat content.
- In some cases condensate can be contaminated or there may be a fear of contamination. In many instances, heat can

HEAT RECOVERY TECHNIQUES

Fig 28 A simple way of recovering heat from contaminated hot condensate



be usefully recovered from contaminated condensate by passing it through a heat exchanger (see Fig 28); however, the value of the heat recovered must always offset the cost of the heat exchanger installation.

The possibility of heat recovery is always worth examining, even when site conditions do not appear to be encouraging.

Handling condensate

Condensate requires specific handling, from the sizing of pipes to whether it can return on its own or needs to be pumped. This subsection examines the points affecting condensate recovery.

Pipework

It is necessary to be aware of what the condensate lines will have to handle. There are three stages to be considered:

1 At production/heater start-up some air may be discharged into the condensate line.

2 As the plant is cold on start-up, there is an exceptionally high rate of condensate (two or three times the normal rate), little or no flash steam and a reduced pressure differential across the steam trap. This last point is important because it shows how unwise it would be to have a high back pressure in the condensate line.

3 As the plant warms up, the amount of condensate reduces to the normal running load, but as the condensate nears steam temperature there will be flash steam formation at the trap discharge.

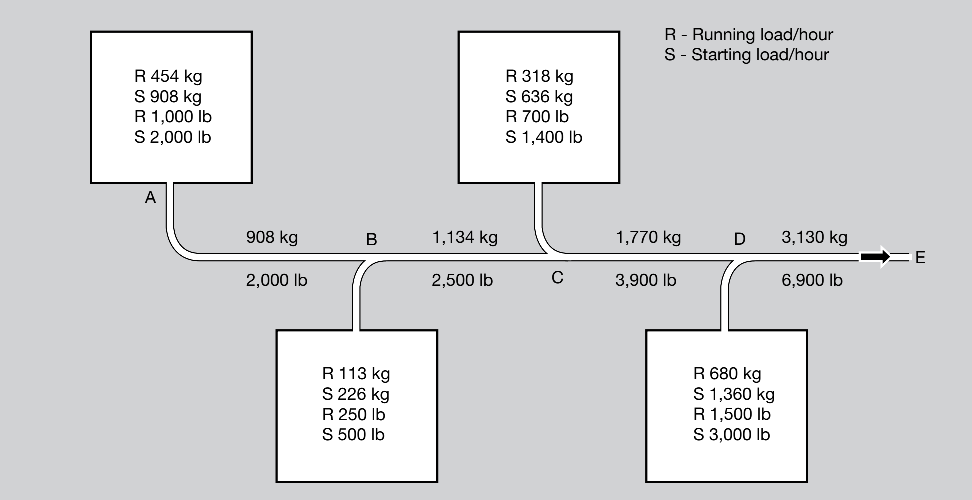
Table 1 shows the carrying capacity of condensate return lines. These can generally be sized on a frictional resistance of 0.8 mbar/m (0.1 in water gauge/ft). Fig 29 shows a typical application.

Table 1 Condensate pipe sizing (starting load - average conditions)

Pipe size mm	Pipe size in	Maximum Capacity (kg/hr)	Starting load (lb/hr)
15	$^1/_2$	160	350
20	$^3/_4$	370	820
25	1	700	1,550
32	$1^1/_4$	1,500	3,300
40	$1^1/_2$	2,300	5,000
50	2	4,500	9,900
65	$2^1/_2$	9,000	20,000
80	3	14,000	31,000
100	4	29,000	63,000

HEAT RECOVERY TECHNIQUES

Fig 29 Typical example of load assessment



From Table 1 the sizes can now be determined as:

- A to B carrying 908 kg/hr (2,000 lb/hr) size 32 mm ($1^1/_4$ in)
- B to C carrying 1,134 kg/hr (2,500 lb/hr) 32 mm ($1^1/_4$ in)
- C to D carrying 1,770 kg/hr (3,900 lb/hr) 40 mm ($1^1/_2$ in)
- D to E carrying 3,130 kg/hr (6,900 lb/hr) 50 mm (2 in).

When condensate is being recovered from plant using steam at higher pressures, the condensate return piping should be generously oversized to cater for the excess of flash steam. Better still, the flash steam should be recovered and put to good use as low pressure steam, which has the dual advantage of making the most use of the heat available and at the same time relieving the load on the condensate return.

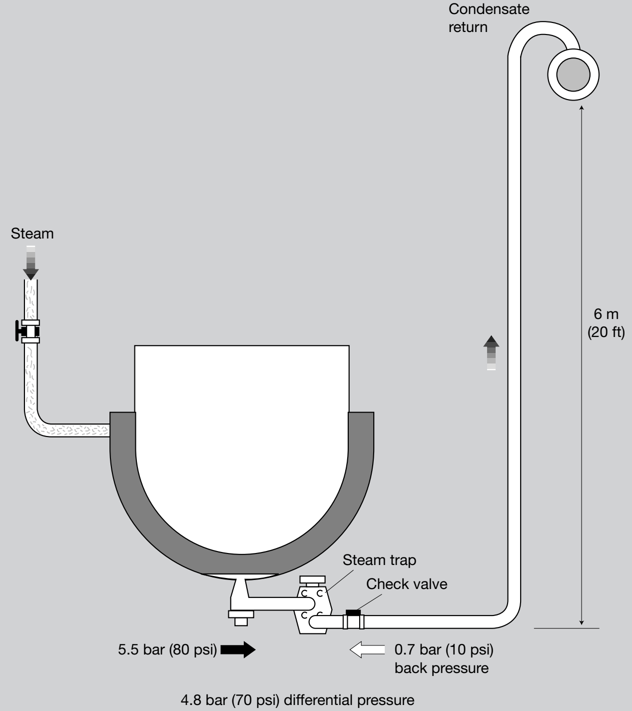
Condensate lifting and back pressure

Most processing plant is at floor level. For convenience of installation, maintenance and to avoid obstruction, condensate return lines are customarily carried at high level. The steam pressure available at the trap lifts the condensate on discharge to the higher level, providing that the trap has a pressurised body.

Basically, for each 0.1 bar pressure at the trap, the condensate can be lifted 1 m (2 ft for each 1 psi pressure). This not only presents a back pressure, but also reduces the pressure differential over the trap. Consideration must therefore be given to whether there will always be adequate steam pressure at the trap to overcome the back pressure, and whether the trap will have sufficient capacity under these conditions.

HEAT RECOVERY TECHNIQUES

Fig 30 Process jacketed pan, with lift to condensate return line



A check valve should always be fitted after the trap as shown in Fig 30 to prevent the column of water flooding back into the plant on shut - down.

If the same plant was supplied with steam at 1 bar (15 psi), theoretically there would still be a positive pressure differential available to clear the condensate against the back pressure. This would be extremely risky because the pressure drop in the plant, especially under start-up conditions, would bring the pressure at the trap down to well below the back pressure, with resultant waterlogging of the plant.

Example of trap sizing

A process jacketed pan is operating with steam at 5.5 bar in the jacket, from which it is assumed that the pressure at the trap is also in the region of 5.5 bar when the pan is up to temperature. There is a lift of 6 m that imposes a back pressure of approximately 0.7 bar after the trap (see Fig 30), so with the 5.5 bar at the trap there will normally be sufficient pressure to overcome the back pressure. The trap must, however, be sized for a differential pressure of 4.8 bar, and this differential will obviously be lower during start-up conditions.

HEAT RECOVERY TECHNIQUES

Pumping condensate

Sometimes there are occasions when condensate cannot be lifted. Even under the most favourable conditions, lifting can be a hindrance on starting up, because a back pressure is created which slows down the clearance of condensate just at a time when this is least wanted. This prevents the clearance of air through the trap, and it also means that whenever maintenance has to be carried out, it may be necessary to drain the column of water. All of these problems can be avoided by allowing the condensate to fall naturally to a receiver, from where it can be pumped to the boilerhouse. It is important that the receiver is adequately vented so that it does not impede the free flow of condensate into and out of it.

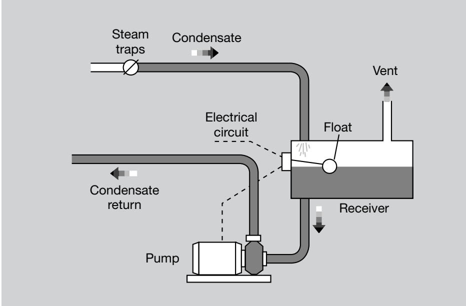
Excess pressure can sometimes be caused by the presence of flash steam. By fitting a flash vessel in the condensate return line before the receiver, the flash steam can be separated from the condensate and the heat fully recovered.

Where condensate is collected into a receiver, electrically driven pumps are frequently used for returning the condensate to the boilerhouse (Fig 31). These pumps are particularly suitable where the discharge lines are long and tortuous, and where capacities are very high. The condensate collected in the receiver will normally be at high temperature, i.e. around atmospheric boiling point. Two problems occur:

- finding a power driven pump which can handle water at this high temperature;
- no power supply available at the convenient collection point for the condensate.

One very practical alternative for delivering the condensate back to the boiler feed tank is the automatic pump or pumping trap (Fig 32). This

Fig 31 Electrically driven pumps for return condensate from a receiver to the boilerhouse



is a simple device using steam as the operating medium. It is installed so that the condensate drains by gravity from the receiver into the pump body through check valve A. Air and vapour are vented through D. As the water level rises it lifts float B, which, at the top of its travel closes vent D and opens steam supply valve C. Steam pressure in the body now forces the water out through check valve E. The discharge of water is followed by the operation of the float which finally closes the steam inlet valve and opens the vent.

One advantage of using this type of pumping trap is that it can be fitted with a simple stroke counter. When the capacity per stroke is known, the amount of condensate handled over any given period can be determined.

Condensate temperature

In some cases the return of all condensate can be a problem by producing water which is too hot to handle. If the problem is simply that, due to

HEAT RECOVERY TECHNIQUES

Fig 32 Automatic pump, or pumping trap, used to deliver condensate back to the boiler feed tank

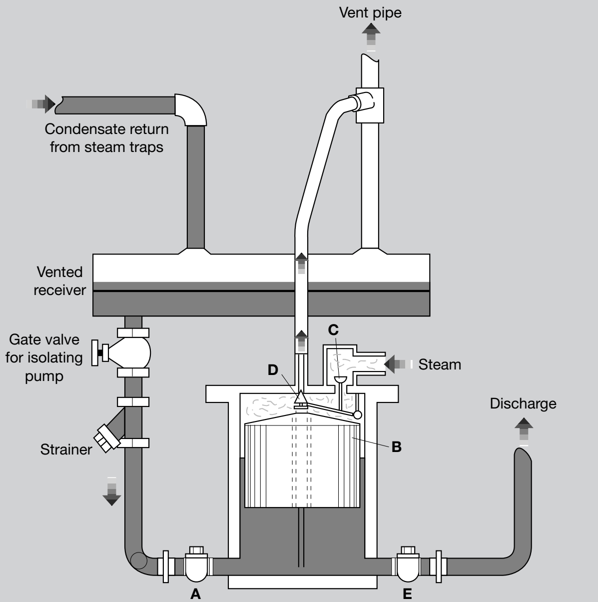
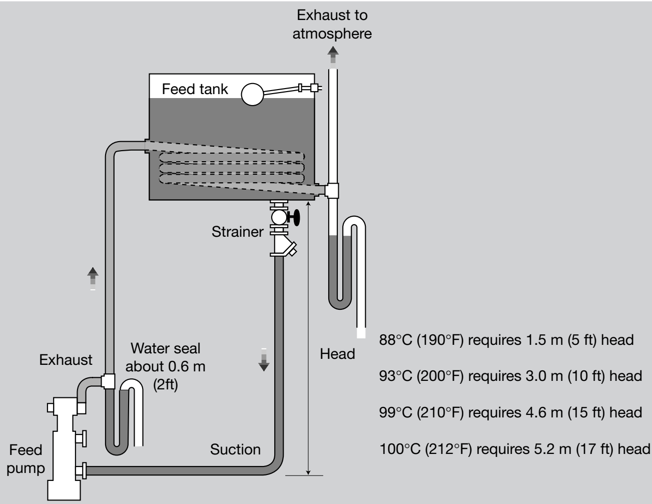
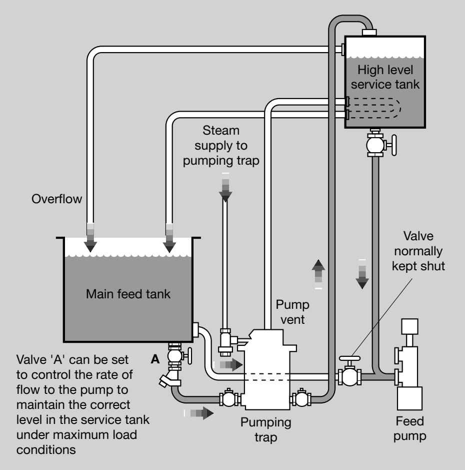


Fig 33 Head/temperature relationship



HEAT RECOVERY TECHNIQUES

Fig 34 High level service tank fed from main tank by a pumping trap



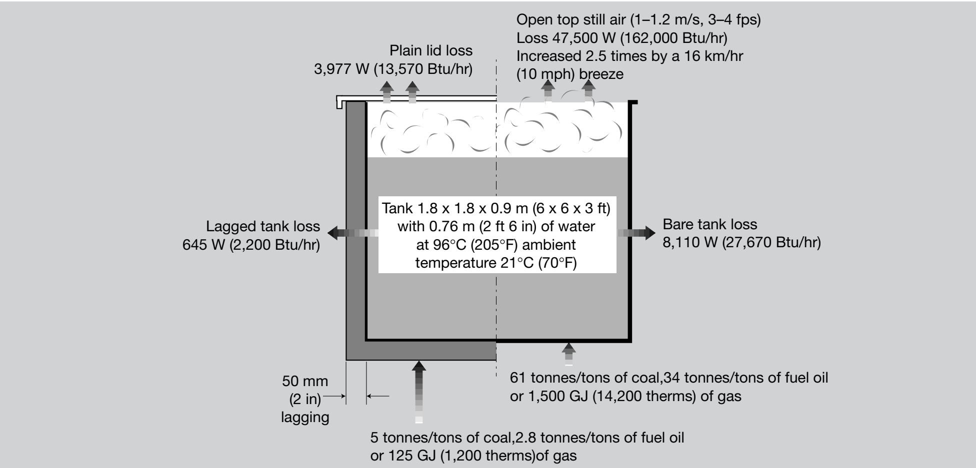
the high temperature, cavitation takes place at the feed pump, it can be overcome by arranging the feed tank so that it provides a positive head over the pump. The head required for any specific temperature is determined by the pressure at the pump inlet, and will vary according to the type of pump used. If in doubt, the manufacturer's advice should be sought. The worst conditions are probably where a positive displacement type of pump is used. Fig 33 shows the minimum head and temperature relationship for this type of pump.

If a steam driven pump is used, the heat from the exhaust can be recovered by passing it through a coil in the feed tank as is shown in Fig 33. In some existing plants it may be difficult to raise the feed tank to the higher level and an alternative is to install a high level service tank - this need not be large - and feed it from the main tank by a pumping trap as shown in Fig 34.

Insulation of the condensate system

It is not uncommon to find that, whereas steam pipework is insulated, condensate pipework is

Fig 35 Total heat losses per year of 6,000 hours



HEAT RECOVERY TECHNIQUES

Table 2 Heat emission from pipes									
Theoretical heat emission from a single horizontal bare steel pipe free exposed in ambient air at temperatures between 10°C and 20°C (50°F and 70°F).									
Temperature difference °C	Pipe size								
	15 mm	20 mm	25 mm	32 mm	40 mm	50 mm	65 mm	80 mm	100 mm
	W/m								
55	59	70	88	110	118	150	180	210	260
60	66	78	98	120	130	170	200	230	290
70	80	95	120	160	160	200	240	280	350
80	96	110	140	170	190	240	290	330	410
90	110	130	160	200	230	270	330	380	480
100	130	150	190	230	260	320	390	450	550
Temperature difference °F	Pipe size								
	1/2 in	3/4 in	1 in	1 1/4 in	1 1/2 in	2 in	2 1/2 in	3 in	4 in
	Btu/Linear ft/hr								
100	63	76	93	114	127	153	187	215	265
120	79	96	117	142	160	193	235	270	335
140	97	118	143	175	195	235	290	330	415
160	115	140	170	210	235	280	345	395	495
175	130	157	190	230	260	315	385	445	550
200	154	185	228	275	310	380	460	530	660

not. Although condensate lines are at a lower temperature, the main object of a condensate recovery system is to recover the heat, so all condensate pipework should be insulated.

Table 2 shows the loss from bare pipes. Under average conditions, insulation will reduce this loss by about 75%.

The boiler feed tank into which the condensate is finally delivered should be adequately insulated and fitted with either:

- a lid containing a vent to atmosphere;
- a floating blanket of hollow plastic balls on the surface of the water. These prevent heat loss from the surface, and reduce the absorption of oxygen into the water.

To give some idea of the difference in heat losses for an insulated and an uninsulated tank, Fig 35 shows a tank, half of which is uncovered and the other half of which is insulated, demonstrating the great value of insulation.

For greater detail on the application of effective insulation, refer to Fuel Efficiency Booklets 8 - *The economic thickness of insulation for hot pipes* - and 19 - *Process plant insulation and fuel efficiency.*

HEAT RECOVERY TECHNIQUES

Example

The steam tables in Appendix 1 show that if the pressure is 7 bar, the temperature of the condensate will be 170°C and will hold 719 kJ/kg of sensible heat. Water at nominal atmospheric pressure cannot be above 100°C, the temperature at which it boils. Thus the water enters the trap with 719 kJ/kg and leaves with 419 kJ/kg, a difference of 300 kJ/kg which the water cannot retain. Part of this energy is used up in re-evaporating some of the water and turning it into steam. This is what is called `flash' steam.

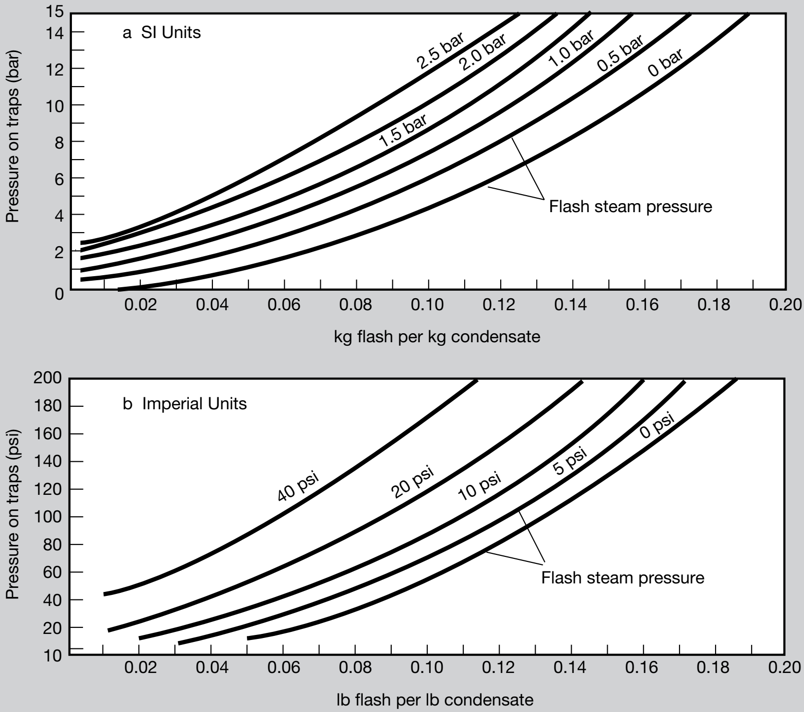
Flash steam heat recovery

Flash steam is as good, as useful and often drier than steam which comes direct from a boiler. In many situations it can be recovered and put to good economic use with the aid of simple equipment.

When steam condenses in a pipe or vessel, it forms condensate which is at the same temperature as the steam.

The greater the difference between the initial pressure and the flash recovery pressure, the

Fig 36 Quality of flash steam available at various operating conditions.



HEAT RECOVERY TECHNIQUES

larger the quantity of flash steam available.

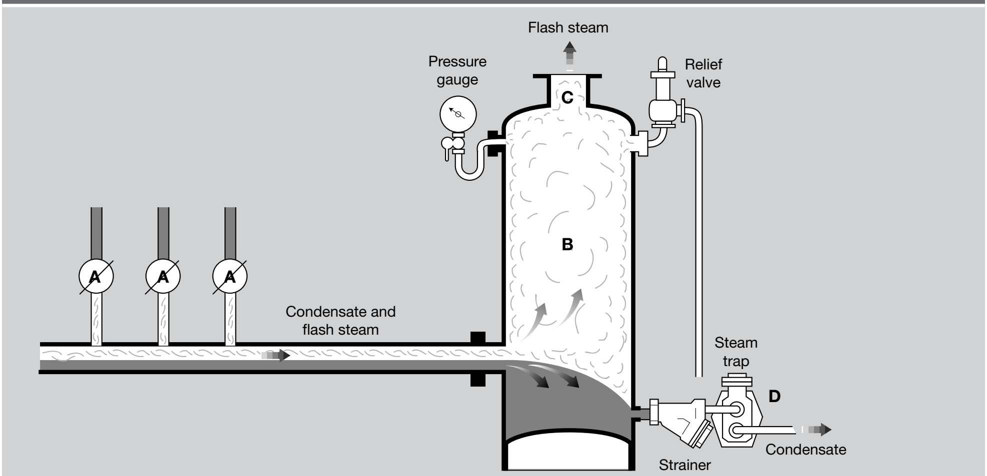
Fig 36 shows how much flash steam is available under various operating conditions. The important basis of flash steam formation is the temperature and heat content of the condensate as it leaves the trap. If thermostatic traps or any other types are used which hold back the flow of condensate until it has given up some of its sensible heat, allowance must be made in calculating the amount of flash steam available. It must also be realised that recovery of flash steam at a low pressure imposes a similar back pressure on the general condensate return system. This could be of importance where the high pressure plant is thermostatically controlled.

The flash steam formed at the traps travels with the condensate along the return lines. If the pipes are uninsulated much of the steam will condense and the heat will be lost to the air. If the pipes are insulated, quite a lot of steam will reach the feed tank.

If the condensate return is above the water level, the flash steam will escape to the air; if the return is below the water level, the flash steam may be condensed and the temperature of the feed will be raised. This will only happen, however, if there is a considerable percentage of cold make-up.

In general, the standard methods of condensate recovery make no real use of the heat in the flash steam which is available at the steam traps. The correct way to use the flash steam, and at the same time overcome many of the difficulties of condensate which is too hot to handle, is to fit a flash vessel either in the common condensate return system or after the traps on big high pressure steam-using units. The flash given off from this can be taken to a low pressure system or unit. Fig 37 shows a simple layout.

Fig 37 Flash vessel



HEAT RECOVERY TECHNIQUES

Condensate at high pressure passes through the traps A to the flash vessel B. The flash vessel is at a lower pressure so that some of the condensate flashes to steam as it leaves the traps. The flash steam is led away through C and the residual condensate from B is led away through the steam trap D, which should preferably be of the float type with continuous discharge.

The flash vessel should be fitted with a pressure relief valve to prevent excess pressure build up should the demand for low pressure steam drop below the rate of flash formation. Ideally the flash vessel should be fitted in a situation where there is a continuous demand for all the flash available. Maximum heat recovery is best obtained by keeping the system pipework to a minimum, thus avoiding unnecessary heat losses.

For this reason a number of small, self-contained recovery units around the plant are generally better than one major unit. The flash vessel and all interconnecting pipework should be insulated.

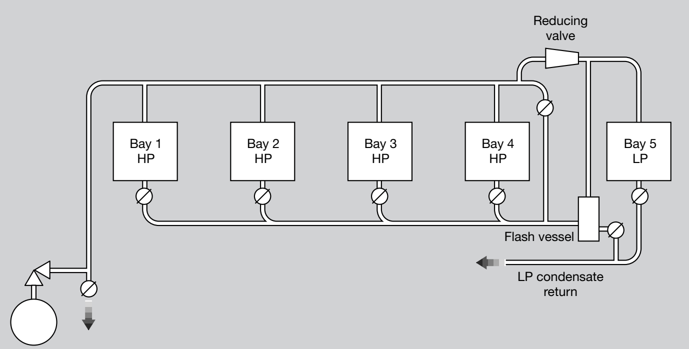
Examples of flash steam heat recovery

There are good and obvious reasons for introducing flash recovery into existing plant, but it is much better to incorporate it as part of the original design.

A heating system can be a good example of building flash heat recovery, where the flash steam can be used advantageously in the initial design of the system. If the building to be heated consists of five bays, then four bays can be served with high pressure (HP) steam from which flash steam is recovered to serve the fifth bay with low pressure (LP) steam, as shown in Fig 38. In this way the capital cost is kept reasonably low, with the advantage of getting the full latent heat out of the system.

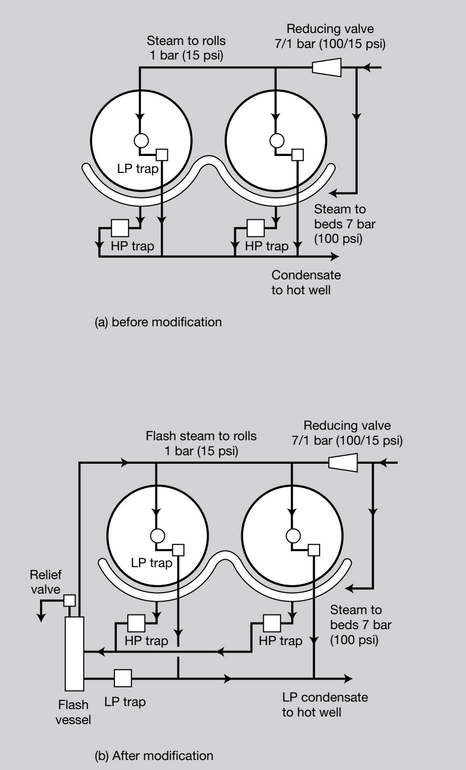
A second example of flash heat recovery, is a two-roll laundry ironer. Fig 39a shows the ironer before modification to use flash steam for the rolls. Steam is fed to the beds at 7 bar (100 psi) and to the rolls at 1 bar (15 psi) through a reducing valve from the high pressure main.

Fig 38 Method of using flash steam in a heating system



HEAT RECOVERY TECHNIQUES

Fig 39 Method of using flash steam in a two-roll laundry ironer



The traps on the beds and the rolls discharge direct to a common condensate main. The main runs back to the hot well which is vented to the atmosphere.

Fig 39b shows the same machine after alteration. Condensate from the flash vessel passes to a low pressure trap and so to the common main.

The flash vessel is shown fitted with a relief valve, not because there is any possibility of the low pressure side being shut down while the high pressure is working, but solely as a safety measure. It is unnecessary to fit a relief valve after the reducing valve on the low pressure steam inlet.

The total equipment needed is one flash vessel, one steam trap, perhaps one relief valve, a few lengths of pipe, fittings and some insulation. The savings to be made are about 9% of the total steam consumption.

Control of flash steam

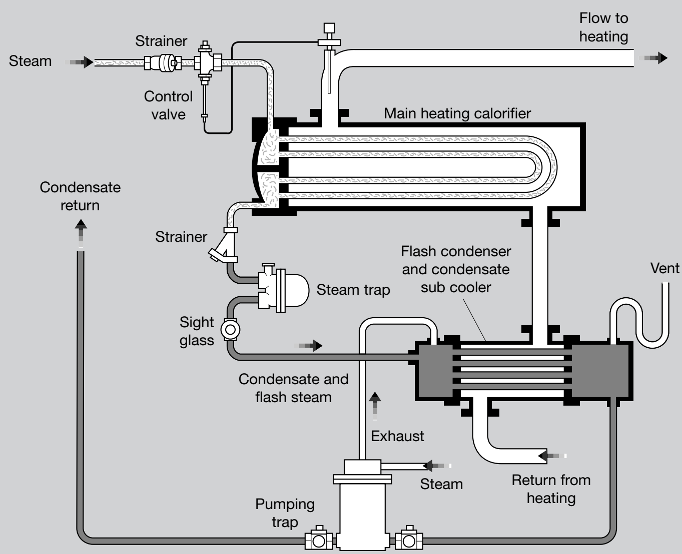
In the examples shown in Figs 38 and 39, there is a cross connection between the high pressure steam supply and the flash steam recovery through a reducing valve. The reducing valve controls the pressure of the low pressure steam supply, admitting make-up when there is insufficient flash steam available to meet the demand. The valve must be a sensitive type, able to detect and respond quickly to changes in load and pressure conditions.

Pressure control and make-up steam may, however, not always be necessary. For example, where steam to water calorifiers are used for space heating it is most economical (for reasons of space and cost) to design the calorifier for use at high pressure, but the disadvantage in doing this is that much valuable heat could be lost in the high temperature condensate discharge. Such loss can be avoided by passing the condensate through a second calorifier or heat exchanger as shown in Fig 40.

In this way some of the heat is extracted from the condensate and flash steam, and put to good use pre-heating the water in circulation and reducing the steam demand on the calorifier.

HEAT RECOVERY TECHNIQUES

Fig 40 Arrangement of calorifiers for heating system



Simple vapour heat recovery

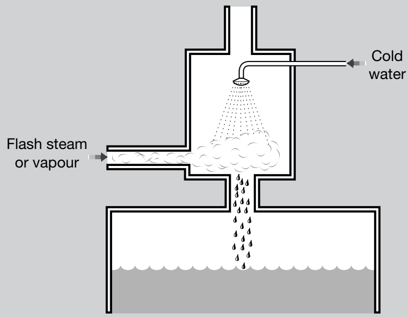
In many processes water is evaporated from the product, during a drying or cooking operation, or in the concentration of a liquor.

The vapour thus produced contains valuable latent heat (about 2,256 kJ/kg (970 Btu/lb) at atmospheric pressure) which, if allowed to discharge freely from the plant, is not only wasteful, but can create a 'fog' nuisance. It is also a frequent cause of damage to the building fabric.

To overcome this problem, vapour should be collected through a ductwork and then spray condensed, using a simple shower or garden spray as shown in Fig 41. This will give a useful supply of hot water which can serve many purposes, such as washing down, providing hot water required in the process or for boiler feed.

Any contaminant carried over with the vapour from the process will now be contained in the water. If this will cause problems, an alternative is to use a heat exchanger.

Fig 41 Spray condensing using a shower or garden spray



SUMMARY/CHECKLIST OF POINTS FOR ACTION

It is no good considering heat recovery from vapour if there is no use for the hot water obtained. The advantage of recovery, however, is great and it is well worthwhile making a careful study in any plant where vapour is produced to see where the water can be utilised.

6 SUMMARY/CHECKLIST OF POINTS FOR ACTION

1 Is the steam used by each department metered?
2 Is a regular check being made on the amount of steam used by each department?
3 Are steam mains properly sized, properly laid out, properly drained and properly vented?
4 Is adequate provision made for expansion?
5 Can separators be used to improve steam quality?
6 Are there leaking joints and glands, or leaking valves and safety valves?
7 Are all steam pipes, flanges and valves insulated?
8 Can redundant steam piping be blanked off or removed?
9 Is the mechanical removal of moisture being efficiently done before drying by heat?
10 Is the material pre-heated by waste heat before processing, if this is practicable?
11 Can bare process plant surfaces be insulated?
12 Are draughts allowed to chill hot rooms or heated surfaces?
13 Is process plant loaded as much as possible and the idle time when hot cut to a minimum?
14 In hot air dryers, is air recirculated to the maximum extent and excess cold air infiltration avoided?
15 Are process temperatures controlled?
16 Are process steam pressures higher than they need to be?
17 When liquids are heated by direct steam injection is the steam pressure as low as possible?
18 Is the steam supplied to process plant as dry as possible? Are peak loads inevitable and, if so, is the boiler house given adequate warning?
19 Can peak processes be staggered?
20 Is the correct type of steam trap used for each application? Is it correctly installed and regularly maintained?
21 Is each trap protected by a strainer and followed by a sight glass?
22 Are check valves fitted after the traps when necessary, especially if the condensate is lifted directly to an overhead return?
23 Are by-passes fitted around steam traps only when essential and are they correctly used?
24 Are traps which can be damaged by freezing insulated when fitted in exposed positions?
25 Is each steam space properly air vented for maximum output and even heating?
26 When condensate is lifted directly from steam traps, can output be improved by gravity drainage to a receiver from which a pump can lift the condensate?
27 Is flash steam allowed to blow to waste?
28 Can flash steam heat be used in a low pressure plant, for pre-heating cold material, for heating water or can it be returned to the boiler feed tank?
29 Is any condensate needlessly wasted?
30 Are condensate return systems and feed tanks insulated?

SOURCES OF FURTHER INFORMATION

31 Is heat recovered from boiler blowdown?

32 Can heat be recovered by heat exchangers from hot liquors or from contaminated condensate?

7 SOURCES OF FURTHER INFORMATION

■ *Department of the Environment Publications:*

Good Practice Guide 18
Reducing energy consumption costs by steam metering.

Good Practice Guide 30
Energy efficient operation of industrial boiler plant

Good Practice Case Study 153
Differential drainage and boiler return system.

Copies of these publications and other literature applicable to the economic use of steam are available from:

Energy Efficiency Enquiries Bureau,
ETSU,
Harwell,
Didcot,
Oxfordshire
OX11 0RA
Tel: 01235 436747
Fax: 01235 433066

■ *The latest news in energy efficient technology:*

Energy Management is a free journal issued on behalf of the DOE which contains information on the latest developments in energy efficiency, and details of forthcoming events designed to promote their implementation.

Copies of *Energy Management* can be obtained through:

Emap Maclaren Ltd,
Maclaren House,
19 Scarbrook Road,
Croydon,
Surrey,
CR9 1QH.

APPENDIX 1 STEAM TABLE (SI UNITS)*

Pressure (bar)	Temperature (°C)	Specific enthalpy Water (kJ/kg)	Evaporation (kJ/kg)	Steam (kJ/kg)	Specific Volume Steam(m^3/kg)
absolute					
0.30	69.10	289.23	2,336.1	2,625.3	5.229
0.50	81.33	340.49	2,305.4	2,645.9	3.240
0.75	91.78	384.39	2,278.6	2,663.0	2,217
0.95	98.20	411.43	2,261.8	2,673.2	1.777
gauge					
0	100.00	419.04	2,257.0	2,676.0	1.673
0.10	102.66	430.2	2,250.2	2,680.4	1.533
0.20	105.10	440.8	2,243.4	2,684.2	1.414
0.30	107.39	450.4	2,237.2	2,687.6	1.312
0.40	109.55	459.7	2,231.3	2,691.0	1.225
0.50	111.61	468.3	2,225.6	2,693.9	1.149
0.60	113.56	476.4	2,220.4	2696.8	1.083
0.70	115.40	484.1	2,215.4	2,699.5	1.024
0.80	117.14	491.6	2,210.5	2,702.1	0.971
0.90	118.80	498.9	2,205.6	2,704.5	0.923
1.00	120.42	505.6	2,201.1	2,706.7	0.881
1.10	121.96	512.2	2,197.0	2,709.2	0.841
1.20	123.46	518.7	2,192.8	2,711.5	0.806
1.30	124.90	524.6	2,188.7	2,713.3	0.773
1.40	126.28	530.5	2,184.8	2,715.3	0.743
1.50	127.62	536.1	2,181.0	2,717.1	0.714
1.60	128.89	541.6	2,177.3	2,718.9	0.689
1.70	130.13	547.1	2,173.7	2,720.8	0.665
1.80	131.37	552.3	2,170.1	2,722.4	0.643
1.90	132.54	557.3	2,166.7	2,724.0	0.622
2.00	133.69	562.2	2,163.3	2,725.5	0.603
2.20	135.88	571.7	2,156.9	2,728.6	0.568
2.40	138.01	580.7	2,150.7	2,731.4	0.536
2.60	140.00	589.2	2,144.7	2,733.9	0.509
2.80	141.92	597.4	2,139.0	2,736.4	0.483
3.00	143.75	605.3	2,133.4	2,738.7	0.461
3.20	145.46	612.9	2,128.1	2,741.0	0.440
3.40	147.20	620.0	2,122.9	2,742.9	0.422
3.60	148.84	627.1	2,117.8	2,744.9	0.405
3.80	150.44	634.0	2,112.9	2,746.9	0.389
4.00	151.96	640.7	2,108.1	2,748.8	0.374
4.50	155.55	656.3	2,096.7	2,753.0	0.342
5.00	158.92	670.9	2,086.0	2,756.9	0.315
5.50	162.08	684.6	2,075.7	2,760.3	0.292
6.00	165.04	697.5	2,066.0	2,763.5	0.272
6.50	167.83	709.7	2,056.8	2,766.5	0.255
7.00	170.50	721.4	2,047.7	2,769.1	0.240
7.50	173.02	732.5	2,039.2	2,771.7	0.227
8.00	175.43	743.1	2,030.9	2,774.0	0.215
8.50	177.75	753.3	2,022.9	2,776.2	0.204
9.00	179.97	763.0	2,015.1	2,778.1	0.194
9.50	182.10	772.5	2,007.5	2,780.0	0.185
10.00	184.13	781.6	2,000.1	2,781.7	0.177
10.50	186.05	790.1	1,993.0	2,783.3	0.171
11.00	188.02	798.8	1,986.0	2,784.8	0.163
11.50	189.82	807.1	1,979.1	2,786.3	0.157
12.00	191.68	815.1	1,972.5	2,787.6	0.151
12.50	193.43	822.9	1,965.4	2,788.8	0.148
13.00	195.10	830.4	1,959.6	2,790.0	0.141
13.50	196.62	837.9	1,953.2	2,791.1	0.136
14.00	198.35	845.1	1,947.1	2,792.2	0.132

** With metrication of the steam tables, the old Imperial definition of sensible heat is now referred to as the specific enthalpy of water. Latent heat is now defined as the specific enthalpy of evaporation and the total heat is defined as the specific enthalpy of steam.*

STEAM TABLE (IMPERIAL UNITS)

Pressure	Temperature (°F)	Sensible heat (Btu/lb)	Latent heat (Btu/lb)	Total heat (Btu/lb)	Volume dry saturated (ft^3/lb)
ins vacuum					
15	179	147	991	1,138	51.41
10	192	160	983	1,143	39.40
5	203	171	976	1,147	31.80
0	212	180	971	1,151	26.80
psi gauge					
1	215	183	969	1,152	25.20
3	221	190	964	1,154	22.50
5	227	196	961	1,156	20.10
7	232	201	958	1,158	18.40
9	237	206	954	1,160	17.00
11	241	210	951	1,162	15.90
13	246	214	949	1,163	15.10
15	250	218	946	1,164	13.90
17	253	222	943	1,165	13.00
19	257	226	941	1,167	12.30
21	260	229	939	1,168	11.70
23	264	233	937	1,169	11.10
25	267	236	935	1,170	10.60
27	270	239	932	1,171	10.30
29	273	242	931	1,172	9.70
31	275	244	929	1,173	9.30
33	278	247	927	1,174	8.90
35	281	250	925	1,175	8.60
37	283	252	923	1,175	8.25
39	286	255	921	1,176	7.95
41	288	257	920	1,177	7.70
43	290	260	918	1,177	7.44
45	292	262	916	1,178	7.21
47	295	264	915	1,179	6.99
49	297	266	913	1,179	6.78
51	299	268	912	1,180	6.60
53	300	270	910	1,181	6.40
55	303	272	909	1,181	6.23
60	308	278	905	1,183	5.84
65	312	282	902	1,184	5.50
70	316	287	898	1,185	5.19
75	320	290	896	1,186	4.91
80	324	295	892	1,187	4.67
85	327	298	890	1,188	4.45
90	331	302	887	1,189	4.24
95	335	305	884	1,189	4.06
100	338	309	882	1,190	3.89
105	341	312	879	1,191	3.74
110	344	316	876	1,192	3.59
115	347	319	874	1,193	3.46
120	350	322	872	1,193	3.34
125	353	325	869	1,194	3.23
130	356	328	867	1,195	3.12
135	358	330	865	1,195	3.02
140	361	333	862	1,196	2.93
145	363	336	860	1,196	2.84
150	366	339	858	1,197	2.76
155	368	341	856	1,197	2.68
160	371	344	854	1,198	2.61
165	373	346	852	1,198	2.54
170	375	348	850	1,198	2.47
175	377	351	848	1,199	2.41
180	380	353	846	1,199	2.35
185	382	355	844	1,199	2.29
190	384	358	842	1,200	2.24
195	386	360	840	1,200	2.19
200	388	362	838	1,200	2.14

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1B *Energy audits for buildings*
2 *Steam*
3 *Economic use of fired space heaters for industry and commerce*
4 *Compressed air and energy use*
7 *Degree days*
8 *The economic thickness of insulation for hot pipes*
9 *Economic use of electricity in industry*
9B *Economic use of electricity in buildings*
10 *Controls and energy savings*
11 *The economic use of refrigeration plant*
12 *Energy management and good lighting practices*
13 *Waste avoidance methods*
14 *Economic use of oil-fired boiler plant*
15 *Economic use of gas-fired boiler plant*
16 *Economic thickness of insulation for existing industrial buildings*
17 *Economic use of coal-fired boiler plant*
19 *Process plant insulation and fuel efficiency*
20 *Energy efficiency in road transport*

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The Government's Energy Efficiency Best Practice Programme provides impartial, authoritative information on energy efficiency techniques and technologies in industry, transport and buildings. This information is disseminated through publications, videos and software, together with seminars, workshops and other events. Publications within the Best Practice Programme are shown opposite.

Further information

For buildings-related publications please contact:
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Energy Consumption Guides: compare energy use in specific processes, operations, plant and building types.

Good Practice: promotes proven energy efficient techniques through Guides and Case Studies.

New Practice: monitors first commercial applications of new energy efficiency measures.

Future Practice: reports on joint R & D ventures into new energy efficiency measures.

General Information: describes concepts and approaches yet to be fully established as good practice.

Fuel Efficiency Booklets: give detailed information on specific technologies and techniques.

Energy Efficiency in Buildings: helps new energy managers understand the use and costs of heating, lighting etc.